CHAPTER D2

FIBERGLASS PIPING SYSTEMS

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Fiberglass reinforced plastic (FRP) piping systems have been successfully used for over fifty years in applications requiring the corrosion resistance of plastics and the strength of metallic systems. FRP piping is readily available in a wide range of types, sizes, and wall thicknesses to meet numerous design requirements. The knowledgeable piping designer can design a successful project by using established standards and criteria. This chapter is intended to provide insight into the standards and criteria available for both aboveground and underground fiberglass piping systems.

TYPICAL APPLICATIONS

Fiberglass piping is used in most industries requiring corrosion-resistant pipe. FRP is used in vent and liquid applications which operate from −40° to 300° F (−40° to 149°C). Fiberglass piping can be constructed of resin which is resistant to acids, caustics or solvents. Abrasion-resistant materials can be added to the FRP piping inside diameter liner and outside cover for excellent slurry wear resistance. Fiberglass pipe is readily available in ½ through 144 inch sizes (DN15 through 3600). Table D2.1 is a brief list of the many applications and industries where fiberglass pipe has been used successfully.

TABLE D2.1 Typical Fiberglass Pipe Applications by Industry

	Industry								
Applications	Chemical process	Food processing	Marine and offshore platforms	Mining and metal refining	Petrochemical and petroleum	Pharmaceutical	Power plants	Pulp and paper	Waste water treatment
Aeration lines									X
Brine slurry lines	X								
Chemical feed lines	X	X		X	X		X	X	X
Column piping			X						
Condensate return	X	X	X		X	X	X	X	
Conduit			X				X	X	
Cooling water lines	X	X			X	X	X		
Disposal well systems	X		X	X	X				X
Downhole tubing and casing			X						X
Effluent drain lines	X	X	X	X	X	X	X	X	X
Fire mains			X	X	X		X	X	
Guttering and downspouts	X	X					X	X	
Oily water			X	X	X				
Scrubber headers	X				X		X		
Seawater lines			X		X		X		
Slurry lines	X						X		
Vent lines	X	X	X	X	X	X		X	X
Water lines	X	X	X		X		X	X	
Waste treatment	X	X	X	X		X	X	X	X
Buried gasoline piping[1]					X				

1. At gasoline service stations.

STANDARDS

The American Society for Testing and Materials (ASTM), American Petroleum Institute (API), British Standard (BS), Deutsche Norm (DIN), and International Organization for Standardization (ISO) publish fiberglass pipe and fittings test methods (see Table D2.2) and standard product specifications (see Table D2.3). The American Society of Mechanical Engineers (ASME) and British Standard publish pressure piping codes (see Table D2.4). Quality fiberglass pipe manufacturers produce products to one or more applicable standards.

TABLE D2.2 Fiberglass Pipe and Fittings Standard Test Methods

Property tested	ASTM standards			DIN standards			ISO standards		
	#	Pipe	Fittings	#	Pipe	Fittings	#	Pipe	Fittings
Beam bending stress & modulus	D 790 modified	Yes	No				ISO 178	Yes	No
Beam deflection, full bore flow	D 2925	Yes	No						
Chemical resistance									
Laminates	C 581	Yes	Yes	53 393	Yes	Yes			
Molding compounds	D 3615	No	Yes						
Pipe, deflected	D 3681	Yes	No						
Circumferential flexural modulus									
Short-term	D 2412	Yes	No	53 769-3	Yes	No	10466	Yes	No
Long-term creep				EN 761	Yes	No	7684	Yes	No
Circumferential tensile strength	D 2290	Yes	No	EN 1393	Yes	No			
Compressive stress & modulus	D 695	Yes	No						
Constituents; % resin, glass, aggregate, filler	D 2584	Yes	No	EN 637	Yes	Yes	7510	Yes	Yes
Dimensions	D 3567	Yes	Yes						
Density	D 792	Yes	Yes	53 479	Yes	Yes			
Dielectric strength	D 149	Yes	Yes						

TABLE D2.2 Fiberglass Pipe and Fittings Standard Test Methods (*Continued*)

Property tested	ASTM standards			DIN standards			ISO standards		
	#	Pipe	Fittings	#	Pipe	Fittings	#	Pipe	Fittings
Electrical resistance, DC	D 257	Yes	Yes						
Indentation hardness, barchol impressor	D 2583	Yes	Yes	EN 59					
Impact resistance	D 2444	Yes	Yes						
Joints, pressure & bending as applicable									
Cemented socket & spigot				EN 1449	Yes	Yes			
Bolted flanges				EN 1450	Yes	Yes			
Socket & spigot with elastomeric seals				EN 1448	Yes	Yes			
Pipe stiffness									
Short-term	D 2412	Yes	No	53 769-3	Yes	No	10466	Yes	No
Long-term creep				EN 761	Yes	No	7684	Yes	No
Pressure, external	D 2924	Yes	No						
Pressure, internal									
Cyclic	D 2143	Yes	No						
Hydrostatic design basis	D 2992	Yes	Yes	53 769-2					
Short-time hydraulic failure	D 1599	Yes	Yes	53 758					
Time to failure, constant pressure	D 1598	Yes	No	EN 1447	Yes	No			
Regression analysis	D 2992	Yes	Yes	53 768	Yes	Yes	10928	Yes	Yes
				EN 705	Yes	Yes			
Ring-bending strain	D 5365	Yes	No						

TABLE D2.2 Fiberglass Pipe and Fittings Standard Test Methods (*Continued*)

Property tested	ASTM standards			DIN standards			ISO standards		
	#	Pipe	Fittings	#	Pipe	Fittings	#	Pipe	Fittings
Shear strength				53 769-1	No	Yes			
Specific gravity	D 792	Yes	Yes						
Stiffness factor									
Short-term	D 2412	Yes	No	53 769-3	Yes	No	10466	Yes	No
Long-term creep				EN 761	Yes	No	7684	Yes	No
Tensile elongation ultimate	D 2105	Yes	No	EN 1393	Yes	No			
Tensile stress & modulus									
Hoop	D 1599	Yes	Yes						
Laminate	D 638	Yes	Yes				527-4	Yes	Yes
Longitudinal	D 2105	Yes	No						
Thermal conductivity	C 177	Yes	Yes						
Thermal expansion, linear coefficient									
Between −30° and 30°C	D 696	Yes	No						
Other temperatures	E 228	Yes	No						

TABLE D2.3 Fiberglass Pipe and Fittings Standard Product Specifications

Product Description	Standard	Pipe	Fittings	Sizes NPS (DN)	Pressure psig (bar)
Fittings					
Contact molded	ASTM D 6041	No	Yes	All	0–150 (0–10)
Dimensions, nominal	ISO 7370	Yes	Yes	1–144 (25–3600)	NA
Flanges, contact molded	ASTM D 5421	No	Yes	1–96 (25–2400)	25–150 (2–10)
Flanges other than contact molded	ASTM D 4024	No	Yes	All	50–500 (3–34)
Gravity flow	ASTM D 3840	No	Yes	8–144 (200–3600)	Gravity
Line pipe, low pressure	API 15LR	Yes	Yes	1–16 (25–400)	up to 1000 (68)
Pressure	ASTM D 5685	No	Yes	1–16 (25–400)	25–1000 (2–68)
Jet fuel lines, belowground	ASTM D 5677	Yes	Yes	All	up to 150 (10)
Joints					
Bell & spigot gasket joints	ASTM D 4161	Yes	Yes	8–144 (200–3600)	up to 250 (17)
Marine pipe & fittings	ASTM F 1173	Yes	Yes	1–48 (25–1200)	All
Laminates, contact molded	ASTM C 582	Yes	Yes	All	All
Pipe					
Casing and tubing	API 15AR	Yes	No	1–10 (25–250)	
Centrifugally cast	ASTM D 2997	Yes	No	All	All
Contact molded	ASTM C 582	Yes	Yes	All	All
Dimensions, nominal	ISO 7370	Yes	Yes	1–144 (10–3600)	NA
Filament wound	ASTM D 2996	Yes	No	1–16 (25–400)	All
Line pipe, high pressure	API 15HR	Yes	No	1–8 (25–200)	500–1000 (34–68)
Line pipe, low pressure	API 15LR	Yes	Yes	1–16 (25–400)	up to 1000 (68)
Machine made classification	ASTM D 2310	Yes	No	NA	NA
Sewer	ASTM D 3262	Yes	No	8–144 (200–3600)	Gravity
Water	ASTM D 3517	Yes	No	8–144 (200–3600)	up to 250 (17)
Industrial wastes & corrosive fluids	ASTM D 3754	Yes	No	8–144 (200–3600)	up to 250 (17)
Process plant piping	BS 6464	Yes	Yes	1–36 (25–1000)	up to 940 (64)
Water supply or sewerage piping	BS 5480	Yes	Yes		
Water systems	AWWA C-950 M45 design manual	Yes	Yes	1–144 (25–3600)	50–250 (3–17)

TABLE D2.4 Fiberglass Pipe and Fittings, Other Standards

Description	Standard
Pressure piping code	
Power piping	ASME B31.1
Process piping	ASME B31.3
British standard, individual plants or sites	BS 7159
Underground installation	ASTM D 6041
	ISO TR 10465-1
Terminology & definitions	ASTM F 412
	ISO 8572
Building services piping	ASME B31.9

RESINS

The resin used in the manufacture of fiberglass pipe, fittings, and adhesives provides for the corrosion resistance of the system. The resin is also used to bond the reinforcing glass together. The glass along with the resin in FRP piping provides for the physical properties of the composite structure. As with the metals used to make pipe, each resin system used in the manufacture of fiberglass pipe has particular strengths and weaknesses.

Custom fiberglass equipment and fiberglass pipe larger than NPS16 (DN 400) are generally made from polyester or vinyl ester resins because of the ease of handling large quantities of this type of resin. Some small-diameter pipe is made from polyester or vinyl ester resins, but most NPS 1 through 16 (DN 25 through 400) pipe are manufactured from epoxy resin systems which are easier to handle in mass-production processes. For special corrosion- or flame-resistant applications outside the capabilities of polyester, vinyl ester, or epoxy resins, pipe made from furan resins or phenolic resins is available.

Epoxy Resins

The chemical resistance and physical properties of an epoxy resin system depend upon both components of the system: the *basic resin* and the *curing or cross-linking agent*. Two general types of epoxy resins are in common usage today: *bisphenol-A epoxies* and *epoxy novolacs*. The bisphenol epoxies are much more widely used because they are more economical and easier to handle during fabrication. The epoxy novolacs are employed where increased temperature resistance and/or better solvent resistance are required. Both types of epoxies can be cured with a great variety of curing agents, and the choice of curing agent has much influence on the properties of the final product. The two most common resin systems used in the manufacture of epoxy fiberglass pipe are bisphenol epoxies cured with aromatic amines and bisphenol epoxies cured with aromatic anhydrides.

In the NPS 1- through 16 (DN 25 through 400) range, bisphenol epoxies cured with aromatic amines produce pipe with the balance of physical, chemical, and economic properties that is needed for most fiberglass piping applications. Pipe made from these resin systems has an upper temperature limit of 250°F (121°C) and is resistant to salt solutions and rather severe alkaline and solvent exposures. Dilute acids are also handled with this type of pipe. If increase solvent resistance is required, an epoxy novolac resin system is recommended.

In the NPS 2- through 16 (DN 50 through 400) range, bisphenol epoxies cured with aromatic anhydrides are used to manufacture pipe for use in oil field and water handling applications where the chemical resistance of an aromatic amine cured epoxy resin is not required. When used within the temperature and chemical limits of the resin system, these pipes give excellent service. These pipes have an upper temperature limit of approximately 150°F (66°C) and are less chemical resistant than pipe made from aromatic amine cured epoxy resin systems. Anhydride-cured resin systems have no resistance to alkaline solutions and are rapidly attacked by water at temperatures above the rated temperature.

Neither of these epoxy resin systems is resistant to strong mineral acids or strong oxidizers.

Polyester Resins

The chemical resistance and physical properties of commercially available polyesters and vinyl esters—a special class of chemical-resistant polyesters—are uniform for a given resin because all of these resins are cured using styrene as the cross-linking agent. When one knows of a successful application of particular polyester or vinyl ester resin, one need not be concerned about the curing agent. During the manufacture of fiberglass pipe, an *initiator* or *catalyst* is added to the styrene-polyester mixture to cause the two components to react and solidify. In almost all chemical services the choice of initiator system is of no consequence. However, the choice of initiator system has been found to affect the chemical resistance of fiberglass pipe in some extremely aggressive chemical services such as hot, wet chlorine, or sodium hypochlorite.

Fiberglass pipe are generally manufactured from any of four types of chemical-resistant polyester resins: vinyl esters and isophthalic, chlorendic, and bisphenol-A fumarate polyesters. Each particular resin has different chemical, physical, and economic properties, and the choice of resin is critical.

Vinyl Ester Resins. Until the development of vinyl ester resins, it was not practical to mass produce small-diameter polyester pipe. Now, however, NPS 1 through 16 (DN 25-400) pipe manufactured from vinyl ester resins is commercially available from several manufacturers. Pipe made from these resins has good physical strength and, in general, better impact strength than other chemical-resistant polyesters. These resins have excellent resistance to oxidizers and strong mineral acids and good resistance to alkaline environments. Standard vinyl esters are limited to 200° to 225°F (93 to 107°C) in most applications, while more costly high-performance vinyl esters are suitable for general use up to 250°F (121°C), and in some special applications have been used in temperatures as high as 350°F (177°C).

Bisphenol-A Fumarate Polyester Resins. The bisphenol-A fumarate polyester is the original high-volume, commercially available, chemical-resistant polyester resin.

This type of resin has been produced for over 35 years and, until the advent of vinyl ester resins, was the resin most widely used in the manufacture of chemical-resistant fiberglass products. The chemical resistance of this type of resin is roughly equivalent to that of vinyl ester resins at temperatures up to 250°F (121°C), but bisphenol-A fumarate resins are more rigid than vinyl esters, and this makes them unsuitable for the manufacture of small-diameter pipe on mass-production equipment. The rigidity of this resin is the major reason for its displacement by vinyl esters from its former position as the most widely used chemical-resistant resin. In large-diameter pipe and large reaction vessels, resin rigidity is not a disadvantage, and this resin is still used in the manufacture of this type equipment, especially when it is to be used in services where this resin has proven successful in past applications.

Chlorendic Polyester Resins. The chlorendic polyester resins have a chlorinated backbone in their molecular structure which makes them particularly well-suited for elevated-temperature applications, up to 350°F (177°C). In most resin classifications there is an increase in rigidity when chemical structure changes are made to give increased temperature performance to the resin. Chlorendic resins follow this general rule and are more rigid than bisphenol-A fumarate resins. The molecular structure of chlorendic resins gives them excellent resistance to concentrated mineral acid and highly oxidizing environments, but poor resistance to alkaline solutions. The solvent resistance of these resins is very good when compared to other polyesters.

Isophthalic Polyester Resins. The isophthalic polyesters are the least expensive and least chemical resistant of the corrosion-resistant polyester resins. For service temperatures up to 180°F (82°C), these resins generally have good resistance to water, dilute acids, and very weak alkaline solutions, and good resistance to petroleum solvents such as gasoline and oil. There are many grades of isophthalic polyester resins. It is important to choose an isophthalic polyester which is compatible with the service being handled.

Other Resins

Furan resins are difficult to work with, and this presently limits their application to systems which require the unique blend of superior acid, alkali, and solvent resistance at temperatures up to 300°F (149°C) offered by these resins. However, furan resins are not suitable for handing oxidizing services.

Phenolic resins also require special processing techniques which limit their economical application to systems that require superior acid and solvent resistance at temperatures to 300°F (149°C). Phenolic resins are often used in flame-resistant duct applications.

MANUFACTURING PROCESSES

Hand Layup

Hand layup or *contact molding* is the simplest method used to make fiberglass pipe and fittings. The part is made over a male mold which forms the inside diameter of the piping component. Glass veil or synthetic nexus is saturated with resin, then applied to the mold, creating a 10 to 20 mil (0.25 to 0.50 mm) thick resin-rich inner surface for the part. This inner liner contains about 90 percent resin and is very corrosion resistant and somewhat abrasion resistant. Most hand layup pipes and fittings have from 50 to 250 mil (1.3 to 6.4 mm) thick corrosion barriers. The corrosion barrier is created by saturating fiberglass mat with resin and then applying it over the resin-rich inner surface. The mat layers contain about 60 percent resin. The corrosion barrier or liner thickness is the total thickness of the veil, nexus, and mat layers. The structural strength of the piping component is created in the reinforced wall of the part. The reinforcement is created by saturating mat or alternating layers of mat and woven roving with resin and applying to the outer surfaces of the corrosion barrier. The number of layers and type of reinforcing glass used depends on the strength requirements for the part. A corrosion barrier can be applied to the outer surface of the part for applications requiring corrosion or abrasion-resistance on the outside diameter.

Hand layup pipe and fittings are typically used in severe or critical applications. As the name implies, hand layup parts are made using manual operations and are usually more expensive than machine-made fiberglass parts. Hand layup parts used for severe and critical applications are also made with up to 10:1 safety factors, which also adds to cost. Hand layup piping is usually provided with plain ends and is joined using butt and wrap joints.

Filament Winding

Filament-wound fiberglass pipe and fittings are machine-made products made on a rotating male mold. The mold forms the inside diameter of the part. Filament-wound parts are made with or without resin-rich interior corrosion barriers. Corrosion barriers are made the same as with the hand layup process but may be applied by hand or by the machine. The reinforced wall for filament-wound pipe and fittings is made by drawing glass roving through a resin bath or with a resin-impregnated tape. The resin-saturated roving or tape is placed on the outside of the corrosion barrier by a fiber placement head (see Figure D2.1a). The fiber placement head

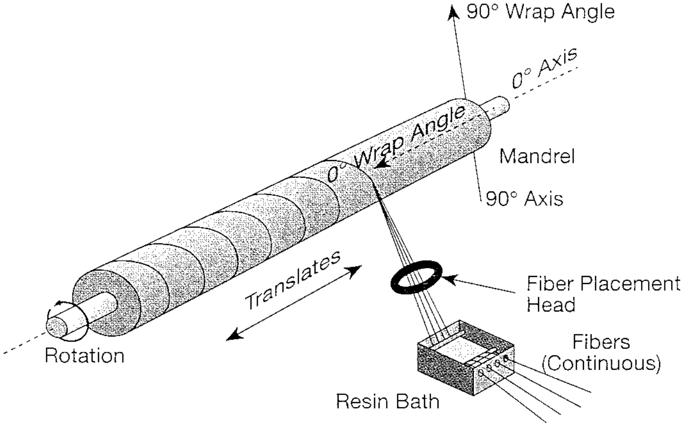


FIGURE D2.1a The filament winding process.

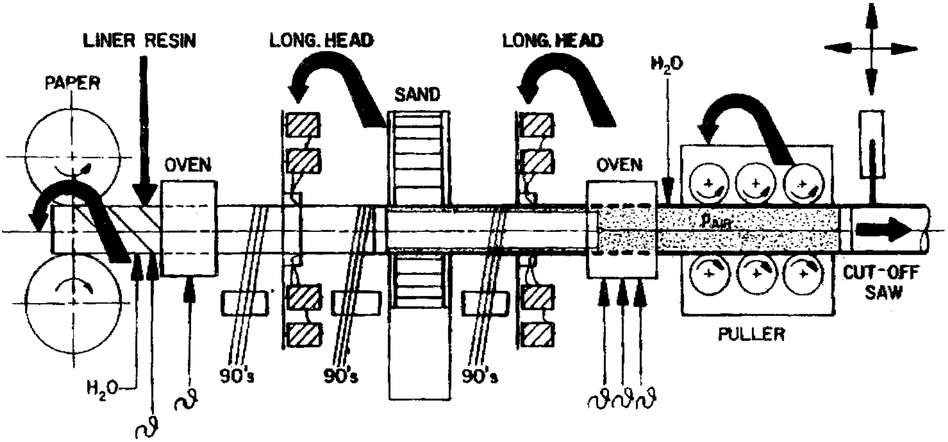


FIGURE D2.1b Continuous filament winding process.

travels in relation to the rotating mold to properly position the reinforcement on the part. The roving or tape-on filament-wound pipe is usually placed on the part at a helical angle. This angle is normally optimized for maximum internal pressure ratings but may be changed for improved pipe stiffness, axial strength, or unsupported span spacing. The number of layers of reinforcement used on filament wound parts is determined by the strength requirements for the part. A barrier can be added to the exterior of filament-wound products for corrosion or abrasion protection.

Another manufacturing process, known as the *continuous filament winding process,* is used for some fiberglass piping products. The advantages of this process are that the pipe is produced continuously and glass angles can be changed to optimize strength (see Fig. D2.1b). The longitudinal glass heads rotate around the tube passing through the center, which is also rotating. Changing one or both speeds of rotation and the rate at which the tube is travelling will change the angle at which the glass is applied. Typically, the goal is to apply the glass nearly longitudinally as this best utilizes the high tensile strength of the glass. The circumferential glass is applied at fixed stations with an application angle of approximately 87°. Glass applied circumferentially will optimize the hoop strength of the pipe as, again, the high tensile strength of the glass is best utilized. The number of longitudinal and circumferential layers can be changed as well to produce a product which has high hoop strength, with more circumferential layers, or longitudinal strength, with more longitudinal layers.

Filament-wound pipe and fittings are used in a broad range of applications. Filament-wound pipe is available with thin walls suitable for light duty applications through very heavy walls suitable for severe or critical applications. The installed cost of filament-wound pipe and fittings can be competitively priced against many metallic and thermoplastic piping systems required in difficult piping applications. Filament-wound pipe and fittings are available with the complete range of joining methods.

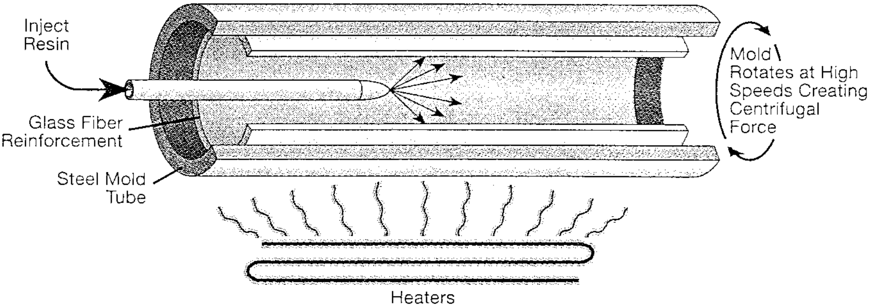


FIGURE D2.2 The centrifugal casting process.

Centrifugal Casting

Centrifugal casting is used to make both glass-fiber-reinforced thermosetting resin pipe and glass-fiber-reinforced plastic mortar pipe. Centrifugal casting is not used to make fiberglass fittings. In the centrifugal casting process the pipe is made inside a steel mold tube which can be rotated at high speeds, creating significant centrifugal force (see Fig. D2.2), Glass-fiber-reinforced thermosetting resin pipe is made by first positioning fiberglass fabrics in the mold tube. The mold is then rotated while a controlled amount of resin is injected into the tube. The very high centrifugal forces of the spinning tube drive the resin through the glass fibers and displace any air in the fibers. Excess resin is injected into the tube which forms a pure resin corrosion and abrasion barrier on the pipe inside diameter. The mold is heated, which aids in the cure of the pipe. A corrosion barrier can be added to the outer surface of the pipe if required for the application.

Centrifugal cast glass-fiber-reinforced thermosetting resin pipe is used in a broad range of applications. It is available with medium walls suitable for moderate applications to heavy walls suitable for severe or critical applications. The installed cost of centrifugal cast pipe can be competitively priced against many metallic and thermosetting piping systems required in difficult piping applications. Centrifugally cast glass-fiber-reinforced thermosetting resin pipe is typically joined with straight socket adhesive, flanged, butt and wrap, threaded, or mechanical joints.

Centrifugal cast glass-fiber-reinforced plastic mortar pipe is made by dispensing a silica and resin mortar mix into a rotating mold tube. The mortar mix creates the reinforced wall of the pipe. The corrosion liner is created by dispensing a mixture of chopped glass and resin into the inside diameter of the resin mortar mix.

Centrifugal cast glass fiber reinforced plastic mortar pipe is used mainly in buried applications but can be used above grade. Mortar pipe has excellent hoop and axial compressive strength, which makes it ideal for tunneling applications. Centrifugal cast glass-fiber-reinforced plastic mortar pipe is typically joined with mechanical joints. Flanged and butt and wrap joints are also available.

Press Molded

Press molding is used to make fittings but not pipe. In this process a mixture of resin, chopped glass, and fillers, called *premix,* is placed in matched metal mold.

The mold is usually closed by a hydraulic press which forces the premix to take the shape of the mold. The mold is heated to accelerate the cure of the part.

Since press molding of fittings is highly automated, press-molded fittings are usually lower in cost than fittings made by other methods. Press-molded fittings can be very corrosion-resistant but typically have heavy walls to achieve desired physical strength. Press-molded fittings are available with bell and spigot, straight socket, and flanged joints.

Resin Transfer Molding

Resin transfer molding is used to make fiberglass fittings only. Resin transfer molded fittings are made by placing glass, veil, and nexus into a mold. After the mold is closed, resin is injected into the mold and cured. Resin transfer molding applications include the outer shell for double contained fiberglass piping systems.

Mitered

Special, low-volume, and large-diameter fiberglass fittings are often made from mitered pipe. The mitered pipe is joined with a butt and wrap joint to form the fitting. Mitered fittings are typically provided with plain ends for butt and wrap joints.

JOINING SYSTEMS

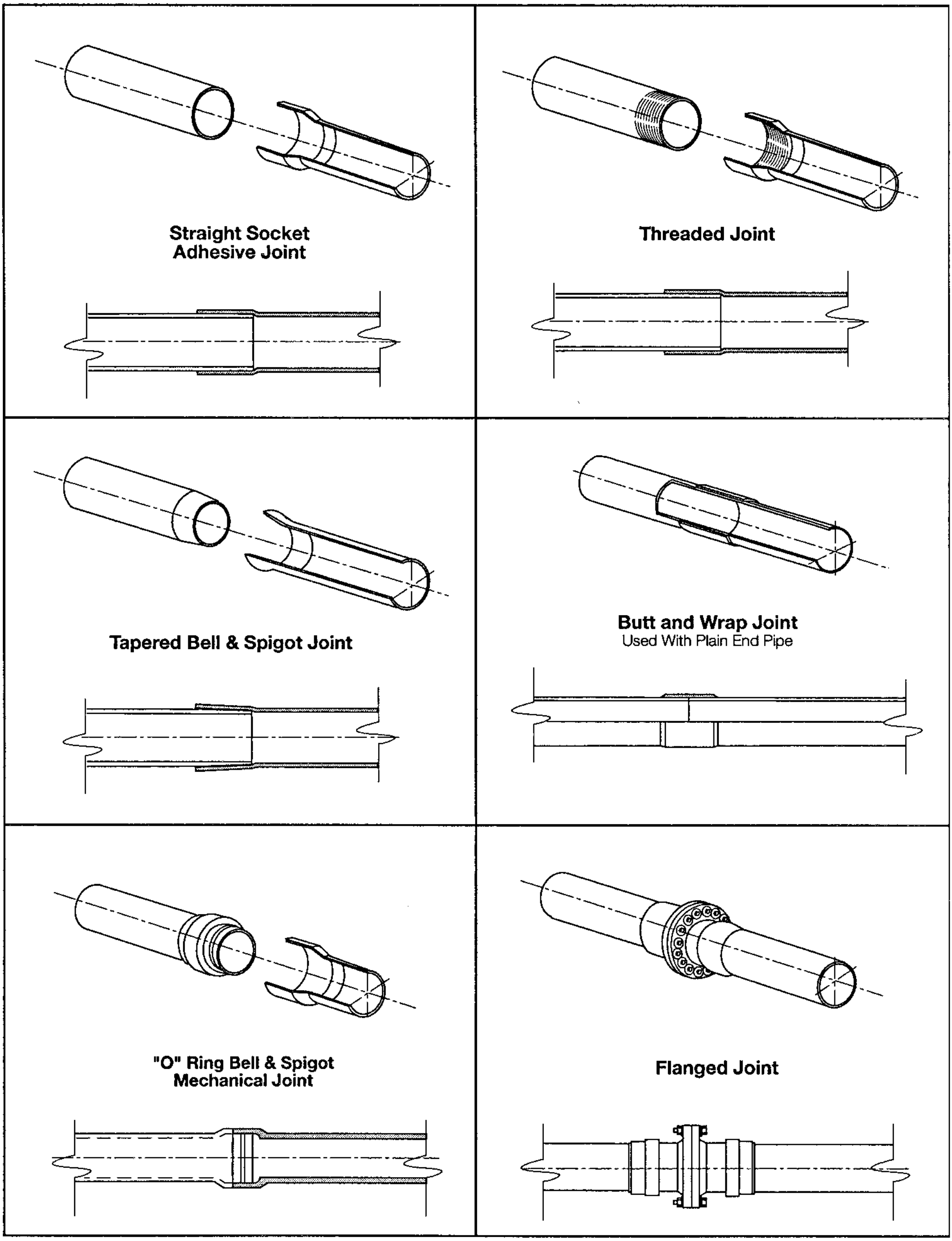
Fiberglass piping is available with a wide range of joining systems to fit the particular application. Available are bell and spigot joints, straight-socket joints, flanged joints, butt wrap joints (also known as butt and strap joints), O-ring joints, bell and spigot joints, threaded joints, and mechanical joints. See Fig. D2.3.

Bell and Spigot Joint

Tapered bell and spigot joints are available in all sizes of fiberglass piping. They include a matched taper for an interference fit which gives a very high strength, thin glue line. The joints are adhesively bonded, usually with a two-part adhesive which is supplied by the piping manufacturer. Tapered bell and spigot joints are used in both low- and high-pressure applications. These joints are typically stronger in pressure and axial tensile capability than the pipe being joined. Bell and spigot joints do require field tapering of joints which are used in less than full length. Specialized field tapering tools are available from the pipe manufacturers. A special type of threaded and bonded tapered bell and spigot joint is also available. The threads in the tapered interference joint are used to hold the joint together during the cure time. This type of joint is claimed to be highly reliable.

Straight-Socket Adhesive Joints

Straight-socket adhesive joints are available (in sizes from NPS 1 through 16 (DN 25 through 400). Some manufacturers limit these joints to NPS 14 (DN 350). The



Straight Socket Adhesive Joint

Threaded Joint

Tapered Bell & Spigot Joint

Butt and Wrap Joint
Used With Plain End Pipe

"O" Ring Bell & Spigot Mechanical Joint

Flanged Joint

FIGURE D2.3 Fiberglass pipe joining systems.

socket in the fitting is essentially straight but may include a slight taper for centering purposes. This type of joint is adhesively bonded. A land in the bottom of each fitting used in this type of piping system ensures accurate laying lengths and close-tolerance piping. Adhesively bonded straight-socket joints are typically stronger in pressure and axial tensile capabilities than the fittings in the piping system.

Flanged Joint

Flanged joints are available in all fiberglass pipe sizes. The flanges are available with industry standard bolt patterns such as ANSI, DIN, ISO, or JSI bolt patterns. Flanges are typically used to connect to other piping systems and equipment or for piping systems which must be opened for inspection or cleaning. Fiberglass flanges are also available in vanstone style.

Butt and Wrap Joint

Butt and wrap joints are available in all sizes of fiberglass piping. Butt and wrap joints are used almost exclusively in hand lay-up piping systems or in filament-wound piping systems larger than NPS 14 (DN 350) or NPS 16 (DN 400), depending upon manufacturer. A butt and wrap joint is used to join two pieces of plain-end pipe or a pipe and fitting. The joint is made by first placing a corrosion barrier, similar to the corrosion barrier used in the pipe and fittings, on the interior or exterior of the pipe. After the corrosion barrier is formed, the mechanical strength of the system is ensured by using saturated reinforcement which is laid up out of mat and woven roving.

O-Ring Bell and Spigot Joint

O-ring bell and spigot joints are available in NPS 14 (DN 350) and larger sizes of filament-wound pipe and all sizes of polymer concrete pipe. O-ring and bell and spigot joints do require restraining the pipe from axial loads, therefore, it is used mostly for buried pipe. O-ring bell and spigot joints are quick and easy to install, but there is a limited availability of fittings in this style of joint.

Threaded Joint

Threaded joints are available in API eight round and ten round EUE (External Upset) and NPT (Nominal Pipe Taper) threads. The EUE threads are available in 1½ through 7 in nominal sizes and are mainly used for high-pressure line pipe and downhole tubing. The 8 round and 10 round threads conform to API standard B. Fittings are available with the EUE threads for couplings, flanges, elbows, tees, crosses, plugs, and adapters only. NPT threads are typically available in NPS 1 to 6 (DN 25 to 150) sizes. Pressure is limited to 450 psi (3105 kPa) depending on the pipe size. Threaded adaptors for NPT threads are readily available. There are also special coarse threads available on some fiberglass piping systems for quick makeup.

Mechanical Joint

Mechanical joints using O-rings for sealing purposes are available in NPS 2 (DN 50) through NPS 36 (DN 900). One type of mechanical joint uses a retainer pin made of either metal cable or thermoplastic rod to retain the axial loads. Also available are mechanical joints which use coarse threads to retain the axial loads. The mechanical joint with threads is fully reusable.

RESISTANT PROPERTIES

Chemical Resistance

The chemical resistance and life expectancy of fiberglass piping systems is dependent on many factors including type of resin, curing agent, liner material, liner thickness, fillers, and cure profiles. When assessing the suitability of a system, the chemical resistance of the pipe, fittings, and joining materials must be considered. With all of the above variables to consider, the piping manufacturer should be contacted for recommendations for specific applications. The piping manufacturer will need to have the following information for their evaluation.

- Chemicals and concentrations
- Temperatures, operating and upset
- Frequency of use
- Other factors which may determine suitability for use:

  Spills or upsets
  Low or static flow in dilute solvent lines
  Mixing of chemicals which may react in the line
  Steam cleaning
  Abrasives

Table D2.5 is provided as a preliminary guideline only. The temperature ratings range shown is compiled from published information from several manufacturers.

Abrasion Resistance

Fiberglass piping systems with typical corrosion barriers are somewhat abrasion resistant. They can typically handle slurries with particle sizes less than 100 mesh (150 micron) at fluid velocity below 6 ft/sec (1.8 meter/sec). The abrasion resistance can be improved by adding fillers such as fine silica, silicon carbide, or ceramic to the piping's interior or exterior barriers. Table D2.6 shows the ability of different resins and abrasion-resistant additives to resist surface wear. (The lower the wear index, the better is the resistance to wear.) Wear resistance of fiberglass fittings can be improved by using long-radius fittings.

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Acetic acid	°F	75–100	100–210	150–215	225	170
	°C	24–93	38–99	66–102	107	77
Acetone	°F	75–180	125–150	100–200	AMB	NR
	°C	24–82	52–66	38–93	AMB	NR
Acrylic acid	°F	100–120	75–100	100–100	NT	NR
	°C	38–49	24–38	38–38	NT	NR
Adipic acid	°F	225–250	75–200	100–210	NT	NL
	°C	107–121	24–93	38–99	NT	NL
Air	°F	210–300	200–360	225–450	NL	NL
	°C	99–149	93–182	107–232	NL	NL
Alcohol-ethyl	°F	120–180	75–150	80–150	NT	NL
	°C	49–82	24–66	27–66	NT	NL
Alcohol, isopropyl	°F	100–180	80–150	100–150	NT	NL
	°C	38–82	27–66	38–66	NT	NL
Alcohol-methyl	°F	75–150	100–150	100–150	NT	NL
	°C	24–66	38–66	38–66	NT	NL
Alcohol-methyl isobutyl	°F	100–150	100–150	120–150	NT	NL
	°C	38–66	38–66	49–66	NT	NL
Alcohol, secondary butyl	°F	100–175	120–150	120–150	NT	NL
	°C	38–79	49–66	49–66	NT	NL
Allyl chloride	°F	75–120	80	75–80	NL	NR
	°C	24–49	27	24–27	NL	NR
Aluminum chloride	°F	150–300	180–210	210–250	250	170
	°C	66–149	82–99	99–121	121	77
Aluminum fluoride	°F	75–150	70–85	70–85	225	NR
	°C	24–66	21–29	21–29	107	NR
Aluminum hydroxide	°F	150–200	80–180	175–180	225	NL
	°C	66–93	27–82	79–82	107	NL
Aluminum nitrate	°F	150–250	125–200	160–225	NT	140
	°C	66–121	52–93	71–107	NT	60
Aluminum sulfate	°F	210–300	160–210	210–250	250	170
	°C	99–149	71–99	99–121	121	77

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Alums	°F	225–300	210	210–250	NT	170
	°C	107–149	99	99–121	NT	77
Ammonia gas, dry	°F	150–225	80–100	100	250	NL
	°C	66–107	27–38	38	121	NL
Ammonia gas, wet	°F	125–150	100	100	NT	NR
	°C	52–66	38	38	NT	NR
Ammonium carbonate	°F	150–250	75–150	150	225	80
	°C	66–96	24–66	66	107	27
Ammonium chloride	°F	150–270	180–210	210–224	220	170
	°C	66–132	82–99	99–107	104	77
Ammonium fluoride	°F	75–150	85–150	150	225	NL
	°C	24–66	29–66	66	107	NL
Ammonium hydroxide	°F	100–200	100–180	100–150	180	NR
	°C	38–93	38–82	38–66	82	NR
Ammonium nitrate	°F	200–250	150–200	200–250	220	140
	°C	93–121	66–93	93–121	104	60
Ammonium persulfate	°F	100–250	170	180	180	NR
	°C	38–121	77	82	82	NR
Ammonium phosphate	°F	150–200	75–200	210	190	140
	°C	66–93	24–93	99	88	60
Ammonium sulfate	°F	200–300	120–210	210–250	220	170
	°C	93–149	49–99	99–121	104	77
Amyl acetate	°F	75–120	NL	80–120	200	NR
	°C	24–49	NL	27–49	93	NR
Amyl chloride	°F	100	120	120	NR	NR
	°C	38	49	49	NR	NR
Aniline	°F	75–100	100–120	70	250	NR
	°C	24–38	38–49	21	121	NR
Antimony chloride	°F	NR	200–210	NR	225	NR
	°C	NR	93–99	NR	107	NR
Antimony trichloride	°F	150–220	NR	200–200	NR	NR
	°C	66–104	NR	93–93	NR	NR

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Barium carbonate	°F	200–250	180–210	210–250	NT	80
	°C	93–121	82–99	99–121	NT	27
Barium chloride	°F	210–250	180–210	210	200	170
	°C	99–121	82–99	99	93	77
Barium hydroxide	°F	180–220	100–200	150–200	200	NR
	°C	82–104	38–93	66–93	93	NR
Barium sulfate	°F	210–250	200–210	210–250	NT	170
	°C	99–121	93–99	99–121	NT	77
Barium sulfide	°F	210–300	150–200	180–215	150	NR
	°C	99–149	66–93	82–102	66	NR
Beer	°F	200–225	90–200	120–200	NT	80
	°C	93–107	32–93	49–93	NT	27
Benzene	°F	100–150	75	100	NT	NR
	°C	38–66	24	38	NT	NR
Benzene sulfonic acid	°F	100–220	125–200	125–215	200	NR
	°C	38–104	52–93	52–102	93	NR
Benzoic acid	°F	100–220	150–210	210	250	170
	°C	38–104	66–99	99	121	77
Black liquor (pulp mill)	°F	100–225	150–180	180–225	NL	NR
	°C	38–107	66–82	82–107	NL	NR
Borax	°F	225–250	200–210	210	NL	170
	°C	107–121	93–99	99	NL	77
Boric acid	°F	200–225	180–210	200–210	200	170
	°C	93–107	82–99	93–99	93	77
Bromic acid	°F	150	NL	150	NT	NL
	°C	66	NL	66	NT	NL
Bromine water	°F	100–150	100	100–190	NT	NL
	°C	38–66	38	38–88	NT	NL
Butadiene, gas	°F	100–150	100	100	NT	NL
	°C	38–66	38	38	NT	NL
Butane, gas	°F	75–150	100	100	NL	NL
	°C	24–66	38	38	NL	NL

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Butyl acetate	°F	AMB–150	NL	80	220	NR
	°C	AMB–66	NL	27	104	NR
Butyl cellosolve	°F	150	100	100	NT	NR
	°C	66	38	38	NT	NR
Butyric acid	°F	150–200	80–210	120–210	200	80
	°C	66–93	27–99	49–99	93	27
Calcium bisulfite	°F	200–270	180–200	180 180 180	NL	140
	°C	93–132	82–93	82 82 82	NL	60
Calcium carbonate	°F	150–300	100–200	180–200	NT	160
	°C	66–149	38–93	82–93	NT	71
Calcium chlorate	°F	150–200	100–210	210–250	NT	150
	°C	66–93	38–99	99–121	NT	66
Calcium chloride	°F	210–300	200–210	215–250	250	170
	°C	99–149	93–99	102–121	121	77
Calcium hydroxide	°F	150–200	100–180	150–210	225	NL
	°C	66–93	38–82	66–99	107	NL
Calcium hypochlorite	°F	100–150	100–200	150–180	NT	NR
	°C	38–66	38–93	66–82	NT	NR
Calcium nitrate	°F	150–250	125–210	210–215	220	170
	°C	66–121	52–99	99–102	104	77
Calcium sulfate	°F	200–250	200–210	210–250	250	170
	°C	93–121	93–99	99–121	121	77
Carbon dioxide gas	°F	225–250	200–210	200–350	NT	NL
	°C	107–121	93–99	93–177	NT	NL
Carbon tetrachloride	°F	100–150	90–180	125–200	225	NR
	°C	38–66	32–82	52–93	107	NR
Carbonic acid	°F	150–180	175	NL	NL	NL
	°C	66–82	79	NL	NL	NL
Castor oil	°F	200–225	150	160–210	NT	NL
	°C	93–107	66	71–99	NT	NL

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Chlorine dioxide gas	°F	75	80–200	180–210	150	NR
	°C	24	27–93	82–99	66	NR
Chlorine gas	°F	125	200–210	210–250	225	NR
	°C	52	93–99	99–121	107	NR
Chloroacetic acid	°F	100–200	75–200	100–135	NT	NR
	°C	38–93	24–93	38–57	NT	NR
Chromic acid	°F	75–150	80–200	90–150	NT	NL
	°C	24–66	27–93	32–66	NT	NL
Chromic fluoride	°F	75	75	75	NL	NL
	°C	24	24	24	NL	NL
Citric acid	°F	200–250	200–210	210–215	190	160
	°C	93–121	93–99	99–102	88	71
Copper chloride	°F	150–250	150–210	210–250	250	170
	°C	66–121	66–99	99–121	121	77
Copper fluoride	°F	200–250	175–200	175–210	NT	NR
	°C	93–121	79–93	79–99	NT	NR
Copper nitrate	°F	150–250	100–210	210–215	220	170
	°C	66–121	38–99	99–102	104	77
Copper sulfate	°F	150–250	150–210	210–250	250	170
	°C	66–121	66–99	99–121	121	77
Crude oil	°F	210–250	200–210	210–250	NL	170
	°C	99–121	93–99	99–121	NL	77
Deionized water	°F	212	180	180–210	NL	170
	°C	100	82	82–99	NL	77
Dichlorobenzene (ortho)	°F	100–150	NL	120	220	NR
	°C	38–66	NL	49	104	NR
Diesel fuel	°F	210–250	150–180	190–225	NL	140
	°C	99–121	66–82	88–107	NL	60
Ethyl acetate	°F	75–150	NL	70	125	NR
	°C	24–66	NL	21	52	NR
Ethyl cellosolve	°F	100–150	NL	NR	NT	NL
	°C	38–66	NL	NR	NT	NL

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Ethyl chloride	°F	75–80	NL	80	220	NR
	°C	24–27	NL	27	104	NR
Ethylene glycol	°F	200–270	200–210	210–225	250	170
	°C	93–132	93–99	99–107	121	77
Fatty acids	°F	200–225	200–210	210–250	250	170
	°C	93–107	93–99	99–121	121	77
Ferric chloride	°F	150–300	150–210	210–225	250	170
	°C	66–149	66–99	99–107	121	77
Ferric nitrate	°F	150–250	150–200	210–215	250	170
	°C	66–121	66–93	99–102	121	77
Ferric sulfate	°F	200–225	200–210	210–215	225	170
	°C	93–107	93–99	99–102	107	77
Ferrous chloride	°F	175–250	165–210	210–225	NT	170
	°C	79–121	74–99	99–107	NT	77
Ferrous sulfate	°F	200–225	200–210	210–215	NT	170
	°C	93–107	93–99	99–102	NT	77
Fluorine gas	°F	75	75–80	75–80	265	NL
	°C	24	24–27	24–27	129	NL
Fluoboric acid	°F	200	180–210	190–210	200	150
	°C	93	82–99	88–99	93	66
Fluosilicic acid	°F	100–200	80–200	80–210	200	NR
	°C	38–93	27–93	27–99	93	NR
Formaldehyde	°F	75–150	75–150	75–260	225	NR
	°C	24–66	24–66	24–127	107	NR
Formic acid	°F	100–140	75–180	100–180	225	100
	°C	38–60	24–82	38–82	107	38
Freon	°F	75–150	75–80	75–100	225	NL
	°C	24–66	24–27	24–38	107	NL
Gas, natural	°F	200–225	180–200	200–210	260	NL
	°C	93–107	82–93	93–99	127	NL
Gasoline	°F	150–225	100–180	100–180	NL	110
	°C	66–107	38–82	38–82	NL	43

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Glucose	°F	200–250	200–210	210–250	NL	110
	°C	93–121	93–99	99–121	NL	43
Glycerine	°F	210–300	200–210	210	NL	170
	°C	99–149	93–99	99	NL	77
Glycol ethylene	°F	200	200	210	NL	NL
	°C	93	93	99	NL	NL
Heptane	°F	150–200	150–210	200–210	250	140
	°C	66–93	66–99	93–99	121	60
Hexane	°F	75–150	100–160	150–160	150	NL
	°C	24–66	38–71	66–71	66	NL
Hexylene glycol alcohol	°F	150	150	150	NL	NL
	°C	66	66	66	NL	NL
Hydraulic fluid	°F	200–225	100–180	180–195	NT	NR
	°C	93–107	38–82	82–91	NT	NR
Hydrobromic acid	°F	100–150	100–180	100–180	NT	NL
	°C	38–66	38–82	38–82	NT	NL
Hydrochloric acid	°F	75–200	75–200	165–230	150	110
	°C	24–93	24–93	74–110	66	43
Hydrocyanic acid	°F	120	150–210	210	200	80
	°C	49	66–99	99	93	27
Hydrofluoric acid	°F	75	100–150	100–150	NT	NR
	°C	24	38–66	38–66	NT	NR
Hydrogen peroxide	°F	80–150	100–150	75–150	NT	NR
	°C	27–66	38–66	24–66	NT	NR
Hydrogen sulfide	°F	150–250	150–180	175–210	NL	140
	°C	66–121	66–82	79–99	NL	60
Hypochlorous acid	°F	120–200	150–180	135–180	NT	NL
	°C	49–93	66–82	57–82	NT	NL
Jet fuel	°F	150–250	120–180	180	NT	140
	°C	66–121	49–82	82	NT	60
Kerosene	°F	150–250	150–200	175–180	NT	140
	°C	66–121	66–93	79–82	NT	60

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Lactic acid	°F	200–225	125–210	210–215	225	130
	°C	93–107	52–99	99–102	107	54
Lauric acid	°F	200–225	125–200	175–215	NT	NL
	°C	93–107	52–93	79–102	NT	NL
Lead acetate	°F	150–250	150–210	210–230	NT	110
	°C	66–121	66–99	99–110	NT	43
Levulinic acid	°F	200–250	200–210	215–230	225	NL
	°C	93–121	93–99	102–110	107	NL
Magnesium carbonate	°F	150–250	150–200	180–200	NL	130
	°C	66–121	66–93	82–93	NL	54
Magnesium chloride	°F	210–270	200–210	225–250	NL	140
	°C	99–132	93–99	107–121	NL	60
Magnesium hydroxide	°F	120–270	125–200	210–215	NL	NL
	°C	49–132	52–93	99–102	NL	NL
Magnesium nitrate	°F	210–300	200–210	210–225	NT	170
	°C	99–149	93–99	99–107	NT	77
Magnesium sulfate	°F	150–270	200–210	210–250	200	150
	°C	66–132	93–99	99–121	93	66
Maleic acid	°F	150–220	200–210	200–250	200	140
	°C	66–104	93–99	93–121	93	60
Mercury	°F	225–270	200–210	210–250	NT	170
	°C	107–132	93–99	99–121	NT	77
Methyl ethyl ketone	°F	75–150	NL	75–125	150	NR
	°C	24–66	NL	24–52	66	NR
Methyl isobutyl carbitol	°F	100–120	NL	NL	NT	NL
	°C	38–49	NL	NL	NT	NL
Methyl isobutyl ketone	°F	100–150	NL	NL	NL	NL
	°C	38–66	NL	NL	NL	NL
Mineral oil	°F	210–270	120	NL	NL	170
	°C	99–132	49	NL	NL	77
Monochlorobenzene	°F	100–150	NL	NL	NL	NR
	°C	38–66	NL	NL	NL	NR

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Naphtha	°F	200–250	125–180	120–210	NT	110
	°C	93–121	52–82	49–99	NT	43
Naphthalene	°F	150–200	100–210	190–210	NL	130
	°C	66–93	38–99	88–99	NL	54
Nickel chloride	°F	210–300	200–210	210–215	220	140
	°C	99–149	93–99	99–102	104	60
Nickel nitrate	°F	200–250	200–210	210–215	220	140
	°C	93–121	93–99	99–102	104	60
Nitric acid	°F	75–120	75–200	120–215	NT	150
	°C	24–49	24–93	49–102	NT	66
Oleic acid	°F	200–225	100–210	200–210	NL	170
	°C	93–107	38–99	93–99	NL	77
Oxalic acid	°F	150–250	120–200	120–215	150	170
	°C	66–121	49–93	49–102	66	77
Perchloric acid	°F	75	75–150	75–150	NT	NR
	°C	24	24–66	24–66	NT	NR
Phenol	°F	75–150	100–150	75–150	NL	NR
	°C	24–66	38–66	24–66	NL	NR
Phosphoric acid	°F	75–225	100–210	210–225	250	170
	°C	24–107	38–99	99–107	121	77
Phosphoric pentoxide	°F	100–200	200	210	NL	NL
	°C	38–93	93	99	NL	NL
Picric acid	°F	75–100	100	100–205	165	NR
	°C	24–38	38	38–96	74	NR
Potassium bicarbonate	°F	150–270	100–180	100–180	NL	NL
	°C	66–132	38–82	38–82	NL	NL
Potassium bromide	°F	200–225	100–200	120–215	200	150
	°C	93–107	38–93	49–102	93	66
Potassium carbonate	°F	100–250	110–180	120–180	200	80
	°C	38–121	43–82	49–82	93	27
Potassium chloride	°F	210–300	200–210	210–215	250	170
	°C	99–149	93–99	99–102	121	77

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Potassium dichromate	°F	200–250	200–210	210	NT	170
	°C	93–121	93–99	99	NT	77
Potassium hydroxide	°F	100–200	100–180	150–180	220	NR
	°C	38–93	38–82	66–82	104	NR
Potassium nitrate	°F	200–300	200–210	210–215	250	170
	°C	93–149	93–99	99–102	121	77
Potassium sulfate	°F	210–270	180–210	210–215	250	170
	°C	99–132	82–99	99–102	121	77
Propane	°F	75–150	100–200	200	NL	NL
	°C	24–66	38–93	93	NL	NL
Silicic acid	°F	200–250	125–200	200–210	NT	170
	°C	93–121	52–93	93–99	NT	77
Silver nitrate	°F	150–250	150–210	210	NL	170
	°C	66–121	66–99	99	NL	77
Soaps	°F	200–250	150–200	210	NL	NL
	°C	93–121	66–93	99	NL	NL
Sodium acetate	°F	150–250	150–210	210–215	225	170
	°C	66–121	66–99	99–102	107	77
Sodium bicarbonate	°F	200–275	100–180	170–180	225	100
	°C	93–135	38–82	77–82	107	38
Sodium bisulfate	°F	150–250	150–210	210–215	225	170
	°C	66–121	66–99	99–102	107	77
Sodium bromide	°F	200–250	200–210	210–215	NL	170
	°C	93–121	93–99	99–102	NL	77
Sodium carbonate	°F	100–205	100–180	180	NL	NR
	°C	38–96	38–82	82	NL	NR
Sodium chlorate	°F	180–250	180–210	210–215	NT	NR
	°C	82–121	82–99	99–102	NT	NR
Sodium chloride	°F	210–300	200–210	210–250	250	130
	°C	99–149	93–99	99–121	121	54
Sodium cyanide	°F	225–250	150–210	210	225	80
	°C	107–121	66–99	99	107	27

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Sodium dichromate	°F	200–250	200–210	210	NT	140
	°C	93–121	93–99	99	NT	60
Sodium ferrocyanide	°F	200–300	150–210	210–215	NL	170
	°C	93–149	66–99	99–102	NL	77
Sodium fluoride	°F	150–250	150–180	150–180	250	80
	°C	66–121	66–82	66–82	121	27
Sodium hydroxide	°F	100–200	100–210	150–180	212	NR
	°C	38–93	38–99	66–82	100	NR
Sodium hypochlorite	°F	75	75–180	110–180	NT	NR
	°C	24	24–82	43–82	NT	NR
Sodium nitrate	°F	200–300	200–210	210–215	225	170
	°C	93–149	93–99	99–102	107	77
Sodium phosphate	°F	200	200–210	210	250	NL
	°C	93	93–99	99	121	NL
Sodium silicate	°F	150–220	160–210	210–215	250	80
	°C	66–104	71–99	99–102	121	27
Sodium sulfate	°F	200–300	200–210	210–215	220	170
	°C	93–149	93–99	99–102	104	77
Sodium sulfite	°F	200	200–210	210–215	NL	80
	°C	93	93–99	99–102	NL	27
Sodium thiosulfate	°F	150	150–200	180	NL	140
	°C	66	66–93	82	NL	60
Stannic chloride	°F	150–270	150–210	210	NL	170
	°C	66–132	66–99	99	NL	77
Stearic acid	°F	150–225	150–210	210–215	NL	170
	°C	66–107	66–99	99–102	NL	77
Sulfamic acid	°F	100–150	100–210	150–210	NL	110
	°C	38–66	38–99	66–99	NL	43
Sulfite liquor	°F	150	200	200	225	NL
	°C	66	93	93	107	NL
Sulfur dioxide	°F	150–250	120–210	225–250	250	NL
	°C	66–121	49–99	107–121	121	NL

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Sulfuric acid	°F	75–205	75–210	120–215	225	170
	°C	24–96	24–99	49–102	107	77
Sulfurous acid	°F	75–200	80–150	100–150	200	NL
	°C	24–93	27–66	38–66	93	NL
Tannic acid	°F	200–225	100–210	100–210	NT	170
	°C	93–107	38–99	38–99	NT	77
Tartaric acid	°F	150–250	200–210	210	250	170
	°C	66–121	93–99	99	121	77
Toluene	°F	100–150	75–80	75–120	225	NR
	°C	38–66	24–27	24–49	107	NR
Trichloroethylene	°F	120–150	NL	NL	NL	NR
	°C	49–66	NL	NL	NL	NR
Triethanolamine	°F	100–150	100–120	120	NL	110
	°C	38–66	38–49	49	NL	43
Trisodium phosphate	°F	100–200	100–210	210–250	NL	120
	°C	38–93	38–99	99–121	NL	49
Tung oil	°F	200	100	200	NL	NL
	°C	93	38	93	NL	NL
Turpentine	°F	100–150	150	100–210	NL	NR
	°C	38–66	66	38–99	NL	NR
Urea	°F	150–200	150	150	225	120
	°C	66–93	66	66	107	49
Vinegar	°F	150–200	NL	210	NL	150
	°C	66–93	NL	99	NL	66
Vinyl acetate	°F	75–150	150–210	NR	NL	NR
	°C	24–66	66–99	NR	NL	NR
Water	°F	200–250	175–200	180–210	NL	160
	°C	93–121	79–93	82–99	NL	71
Water, sea	°F	210–270	175–200	210	NL	170
	°C	99–132	79–93	99	NL	77
Xylene	°F	125–150	75–80	75–120	225	NR
	°C	52–66	24–27	24–49	107	NR

TABLE D2.5 Maximum Temperature Ratings Range by Chemical and Resin Class (*Continued*)

Service/Fluid		Epoxy	Vinyl ester	Novolac VE	Furan	Isophthalic
Zinc chloride	°F	210–250	200	200–310	NL	170
	°C	99–121	93	93–154	NL	77
Zinc sulfate	°F	200–250	200–210	210–350	250	170
	°C	93–121	93–99	99–177	121	77

NL = Not Listed
NR = Not Recommended
NT = Not Tested

The piping manufacturer should be contacted for recommendations for specific abrasive applications. The following information will be needed to make the best recommendation:

- Particle size
- Percent solids
- Particle hardness
- Flow velocity
- Continuous or intermittent service

TABLE D2.6 Derakane Epoxy Vinyl Ester Resins Taber Abrasion Testing[1]

Laminate description	Wear index
Derakane 411	388
Derakane 470	520
Derakane 8084	250
Derakane 411, 10% fine silica	70
Derakane 411, 50% fine silica	38
Derakane 411, 66% fine silica	38
Derakane 411, 20% silicon carbide	25
Derakane 411, 40% silicon carbide	10
Derakane 411, 50% silicon carbide	10

[1] CS-17 Abrasive Wheel, 1000 gram loading

Source: Derakane epoxy vinyl ester resins ''Fabricating Tips'' 10/94

Flame Resistance

Flame-resistant fiberglass piping has been developed that is readily avaliable. These systems usually use phenolic resins or brominated vinyl ester resins with antimony trioxide fillers. ASTM E-84 tunnel test flame spread ratings below 25 can be achieved with both resin systems. Phenolic systems also provide for low smoke generation. Intunescent coatings can also be applied to increase flame resistance.

Weather Resistance

Fiberglass piping systems have been successfully used from the north slope of Alaska to the Sahara desert. Fiberglass piping is less prone to ultraviolet or cold embrittlement and cracking than thermoplastic piping systems. Fiberglass piping also has operating temperature capabilities in excess of ambient temperatures. Surfaces of fiberglass piping systems exposed to sunlight will experience ultraviolet degradation of the resin. This degradation is a surface effect which stops as soon as the glass fibers are exposed. Long-term testing of fiberglass piping typically shows no effect on the physical strength of the components. The surface appearance of the pipe will deteriorate with ultraviolet exposure. The surface can be protected with a resin-rich veil surface, paint, or ultraviolet inhibitors.

PHYSICAL PROPERTIES

The physical properties of fiberglass pipe are dependent on resin type, glass type, manufacturing method, glass orientation, and cure profile. Actual properties may vary significantly between pipes that appears to be similar; therefore the manufacturer's published data should be used for all engineering calculations. Table D2.7 is provided as preliminary information only. Since FRP physical properties are dependent on glass orientation, unit stress and elastic modulus are also dependent on orientation of the load. Fig. D2.4 shows simplified load orientations along with the ASTM standard test method used to measure unit stress and elastic modulus.

TABLE D2.7 Typical Ultimate Physical Properties for Fiberglass Pipe

Property at 75°F (24°C)	Filament-wound epoxy pipe	Centrifugally cast epoxy pipe	Filament-wound vinyl ester pipe	Centrifugally cast vinyl ester pipe	Filament-wound isophthalic pipe
Hydrostatic burst, ASTM D-1599 ultimate stress, psi (kg/cm^2)* modulus of elasticity, psi (kg/cm^2)*	 38,000 (2,700) 3.4E+06 (2.4E+05)	 27,000 (1,900) 2.6E+06 (1.8E+05)	 40,000 (2,800) 3.2E+06 (2.2E+05)	 34,500 (2,400) 2.3E+06 (1.6E+05)	 42,000 (3,000) 3.2E+06 (2.2E+05)
Hydrostatic design stress, ASTM D-2992, psi (kg/cm^2)*	11,000 (770)	11,000 (770)	7,000 (490)	8,000 (560)	7,500 (530)
Axial tensile, ASTM D-2105 ultimate stress, psi (kg/cm^2)* modulus of elasticity, psi (kg/cm^2)*	 15,000 (1,100) 1.8E+06 (1.3E+05)	 35,000 (2,500) 2.8E+06 (2.0E+05)	 9,000 (630) 1.5E+06 (1.1E+05)	 36,000 (2,500) 2.6E+06 (1.8E+05)	 9,400 (660) 1.9E+06 (1.3E+05)
Beam bending, ASTM D-2925 ultimate stress, psi (kg/cm^2)* modulus of elasticity, psi (kg/cm^2)*	 25,000 (1,800) 2.0E+06 (1.4E+05)	 41,000 (2,900) 2.6E+06 (1.8E+05)	 20,000 (1,400) 1.8E+06 (1.3E+05)	 38,000 (2,700) 2.4E+06 (1.7E+05)	 1.3E+06 (0.91E+05)
Axial compressive, ASTM D-695 ultimate stress, psi (kg/cm^2)* modulus of elasticity, psi (kg/cm^2)*	 30,000 (2,100) 2.0E+06 (1.4E+05)	 38,000 (2,700) 2.5E+06 (1.8E+05)	 16,000 (1,100) 1.6E+06 (1.1E+05)	 26,000 (1,800) 2.5E+06 (1.8E+05)	 23,000 (1,600) 8.5E+05 (0.60E+05)
Hoop bending, ASTM D-2412 modulus of elasticity, psi (kg/cm^2)*	2.5E+06 (1.8E+05)	3.4E+06 (2.4E+05)	2.3E+06 (1.6E+05)	3.1E+06 (2.2E+05)	2.2E+06 (1.5E+05)
Coefficient of thermal expansion ASTM D-696, in/in/°F (mm/mm/°C)†	1.0E−05 (1.8E−05)	1.1E−05 (2.0E−05)	1.2E−05 (2.2E−05)	0.87E−05 (1.6E−05)	1.4E−05 (2.5E−05)
Coefficient of thermal conductivity ASTM D-177, BTU/(ft^2)(hr)(°F/in), (W/(m)(°K))†	2.4 (0.35)	0.87 (0.13)	1.7 (0.25)	0.87 (0.13)	1.7 (0.25)
Specific gravity, ASTM D-792†	1.8	1.45	1.8	1.55	2.1
Poisson's ratio, ASTM D-2105 Ratio axial strain-to-hoop strain*	0.26	0.15	0.3	0.15	
Flow factor Hazen-Williams 'C' Manning's 'n' Absolute roughness, ft	 150 0.009 1.7E−05	 150 0.009 1.7E−05	 150 0.009 1.7E−05	 150 0.009 1.7E−05	 150 0.009 1.7E−05

* ***Note 1:*** Based on reinforced wall thickness
† ***Note 2:*** Based on total wall thickness

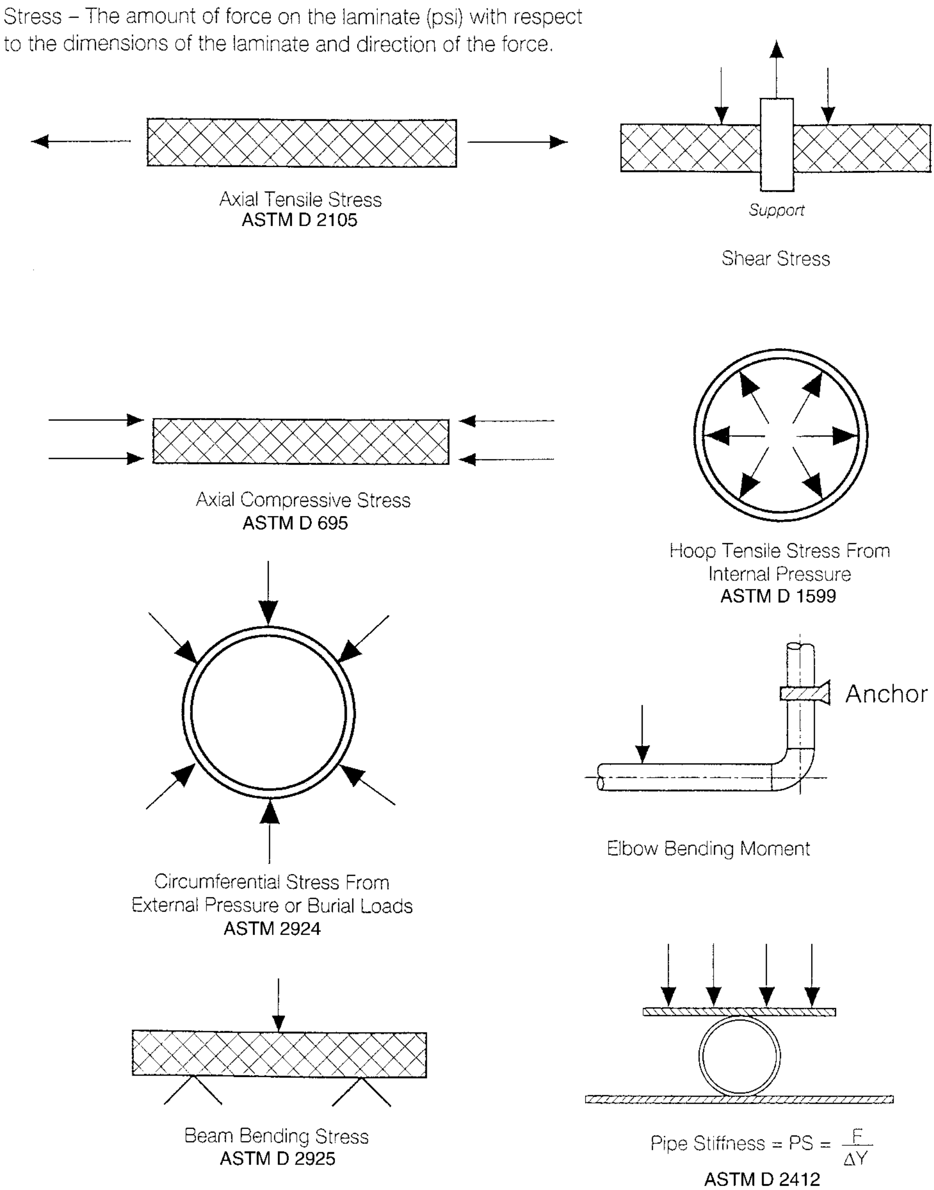


FIGURE D2.4 Simplified load orientation used for determing unit stress and elastic modulus according to ASTM test methods.

BENEFITS AND LIMITATIONS OF FIBERGLASS PIPING SYSTEMS

Fiberglass pipe offers a number of benefits compared to other piping materials, but it also has some significant limitations. The piping designer should review the benefits and limitations when making the piping material selection.

Corrosion Resistance

Fiberglass piping can be manufactured with resins selected to optimize corrosion resistance for a particular application. Corrosion resistance is generally good compared to competitive materials but may have some concentration and temperature limitations.

Installed Cost

The installed cost of FRP pipe is competitive with stainless steel, lined steel, and high-end thermoplastic systems (see Table D2.8 and Fig. D2.5).

TABLE D2.8 Total Material and Labor Cost Index* (Average for Pipe Installed in Process Areas, Inside Buildings, and Outside Buildings, Fiberglass = 1.0)

NPS (DN)	CPVC Schedule 80	PVDF Plastic 160 psi	Polypropylene-lined steel Class 150	A53 Carbon steel Sch. 40 STD.	Stainless steel Sch. 10	Fiberglass 150 psi
1″ (25)	0.10	0.53	0.48		0.31	1.00
1½″ (40)	0.18	1.23	0.82		0.45	1.00
2″ (50)	0.36	2.56	1.53	0.42	0.95	1.00
3″ (80)	0.44	2.47	1.63	0.46	0.93	1.00
4″ (100)	0.49	3.00	1.83	0.50	0.99	1.00
6″ (150)	0.59	4.13	2.09	0.53	1.36	1.00
8″ (200)		4.04	2.07	0.49	1.33	1.00
10″ (250)		4.56		0.50	1.35	1.00
12″ (300)		6.21		0.50	1.36	1.00
14″ (350)				0.51		1.00

Source: Richardson Engineering Services Process Plant Construction Estimating Standards, 1997 Edition

* ***Note:*** Does not include fittings, valves or support devices.

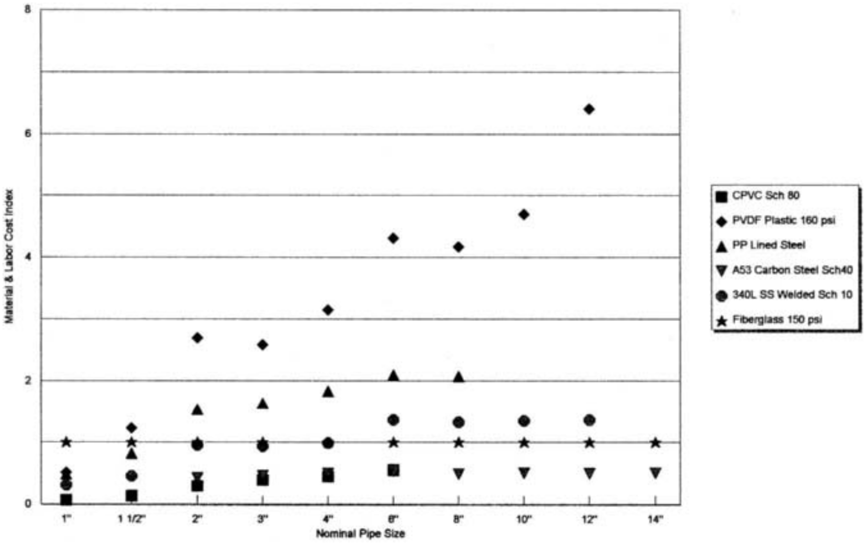


FIGURE D2.5 Piping material and labor (total cost index).

Unsupported Spans

The spans for fiberglass systems can actually be longer than both steel and thermoplastic systems (see Table D2.9 and Fig. D2.6), further reducing the installed cost on aboveground systems.

TABLE D2.9 Support Spacing In Feet at 60°F (Specific Gravity = 1.00)

NPS (DN)	PVC Schedule 80	Steel standard wall	Fiberglass process pipe
1″ (25)	6.0	7.0	12.3
1½″ (40)	6.5	9.0	14.4
2″ (50)	7.0	10.0	15.0
3″ (80)	8.0	12.0	17.4
4″ (100)	9.0	14.0	19.0
6″ (150)	10.0	17.0	21.8
8″ (200)	11.0	19.0	24.4
10″ (250)	12.0	22.0	26.7

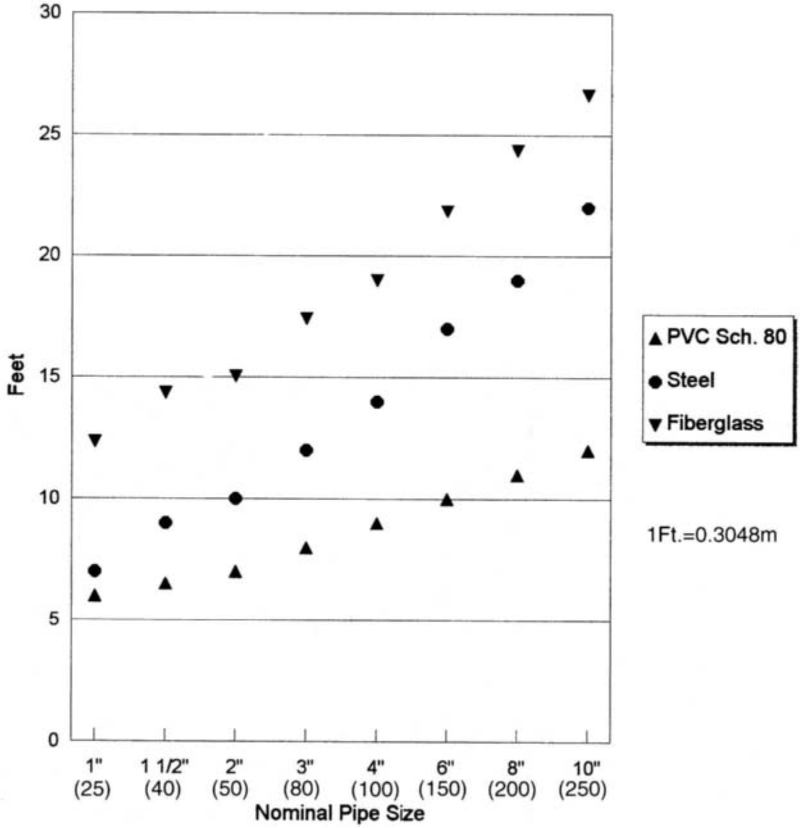


FIGURE D2.6 Support spacing (feet at 60°F).

Thermal Expansion

The thermal expansion of fiberglass pipe is comparatively low (see Table D2.10 and Fig. D2.7) and can be easily controlled using the inherent strength of fiberglass.

Flow Loss

Fiberglass pipe has a smooth bore which typically remains smooth throughout the life of the system. The smooth bore significantly reduces flow loss in both pumped and drainage systems. Flow loss can significantly affect the life cycle cost of pumped systems and pipe size requirements for drainage systems (see Table D2.11 and D2.12).

TABLE D2.10 Piping System Thermal Expansion, Uninsulated Pipe (inches/100 feet)

Temperature change degrees F	PVC	CPVC	Carbon steel	Stainless steel	Typical fiberglass pipe
25	0.90	1.14	0.18	0.27	0.31
50	1.80	2.28	0.36	0.54	0.61
75	2.70	3.42	0.54	0.82	0.92
100	3.60	4.56	0.72	1.09	1.23
125	4.50	5.70	0.90	1.36	1.53
150	5.40	6.84	1.08	1.63	1.84

Temperature Change, °F = $\frac{1}{1.8}$ °C

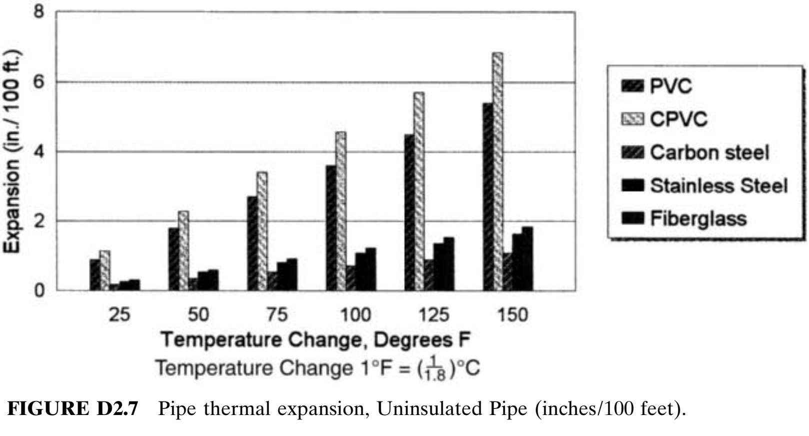


FIGURE D2.7 Pipe thermal expansion, Uninsulated Pipe (inches/100 feet).

TABLE D2.11 Cost Comparison (Steel versus Fiberglass)

Flow rate (gpm):	1200
Pipe length (ft):	3000
Pipe I.D. (in.) (steel):	7.98
Pipe I.D. (in.) (fiberglass):	8.35
Fluid density (lbs/gal):	8.34
Energy cost per kW-hr:	$0.05

Pump efficiency:	80.0%
Pump price* (for steel line):	$7,850.00
Pump price† (for fiberglass line):	$3,920.00
Material & labor per foot (steel):	$13.79
Material & labor per foot (fiberglass):	$24.21
Discount rate:	8.5%

	Hazen-Williams flow coefficient		Total head loss (ft)		Horsepower demand (hp)		Energy consumption (kW-hr)		Total energy cost		Life cycle cost	
	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass
Year: 0											$49,229.00	$76,535.00
1	126.0	150	82.4	47.9	25.0	14.5	204081.3	118493.45	$10,204.06	$5,924.67	$58,633.67	$81,995.53
2	120.5	150	89.6	47.9	27.2	14.5	221800.7	118493.45	$11,090.04	$5,924.67	$68,054.16	$87,028.27
3	109.6	150	106.6	47.9	32.3	14.5	264058.9	118493.45	$13,202.94	$5,924.67	$78,390.85	$91,666.75
4	102.8	150	120.2	47.9	36.4	14.5	297557.0	118493.45	$14,877.85	$5,924.67	$89,126.32	$95,941.84
5	98.2	150	130.8	47.9	39.7	14.5	323850.4	118493.45	$16,192.52	$5,924.67	$99,895.08	$99,882.01
6	94.9	150	139.3	47.9	42.2	14.5	344983.7	118493.45	$17,249.18	$5,924.67	$110,467.88	$103,513.51
7	92.4	150	146.3	47.9	44.4	14.5	362384.8	118493.45	$18,119.24	$5,924.67	$120,703.92	$106,860.52
8	90.5	150	152.2	47.9	46.2	14.5	377012.3	118493.45	$18,850.62	$5,924.67	$130,518.86	$109,945.31

TABLE D2.11 Cost Comparison (Steel versus Fiberglass) (*Continued*)

	Hazen-Williams flow coefficient		Total head loss (ft)		Horsepower demand (hp)		Energy consumption (kW-hr)		Total energy cost		Life cycle cost	
	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass
Year: 9	88.9	150	157.3	47.9	47.7	14.5	389522.0	118493.45	$19,476.10	$5,924.67	$139,865.04	$112,788.44
10	87.6	150	161.7	47.9	49.0	14.5	400374.9	118493.45	$20,018.75	$5,924.67	$148,719.04	$115,408.84
11	86.5	150	165.5	47.9	50.2	14.5	409904.6	118493.45	$20,495.23	$5,924.67	$157,073.64	$117,823.95
12	85.5	150	168.9	47.9	51.2	14.5	418358.2	118493.45	$20,917.91	$5,924.67	$164,932.54	$120,049.86
13	84.7	150	172.0	47.9	52.2	14.5	425923.3	118493.45	$21,296.17	$5,924.67	$172,306.74	$122,101.39
14	84.0	150	174.8	47.9	53.0	14.5	432744.7	118493.45	$21,637.24	$5,924.67	$179,212.08	$123,992.20
15	83.3	150	177.3	47.9	53.8	14.5	438936.4	118493.45	$21,946.82	$5,924.67	$185,667.52	$125,734.88
16	82.8	150	179.5	47.9	54.4	14.5	444589.4	118493.45	$22,229.47	$5,924.67	$191,693.85	$127,341.04
17	82.2	150	181.6	47.9	55.1	14.5	449777.2	118493.45	$22,488.86	$5,924.67	$197,312.89	$128,821.37
18	81.8	150	183.6	47.9	55.7	14.5	454560.1	118493.45	$22,728.01	$5,924.67	$202,546.80	$130,185.73
19	81.3	150	185.3	47.9	56.2	14.5	458988.1	118493.45	$22,949.40	$5,924.67	$207,417.67	$131,443.21
20	80.9	150	187.0	47.9	56.7	14.5	463102.8	118493.45	$23,155.14	$5,924.67	$211,947.19	$132,602.17

* 75 HP close-coupled centrifugal pump, bronze fitted construction
† 40 HP close-coupled centrifugal pump, bronze fitted construction

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TABLE D2.12 Fiberglass versus Coated Cast-Iron (Drainage Pipe Flow Comparison Using the Manning Equation)

Pipe input variables					Manning equation variables		
I.D. of pipe (inches)	Pipe material	Manning roughness	% Pipe used (select ¼, ½, ¾, or F)		Cross-sect. area (ft.)	Wetted perimeter (ft.)	Hydraulic radius
8.000	Steel	0.013	(¾ Full)	75	0.174533	1.047198	0.166667
8.085	Fiberglass	0.009	(¾ Full)	75	0.178261	1.058324	0.168438
3	Steel	0.013	(½ Full)	50	0.024544	0.392699	0.062500
3	Fiberglass	0.009	(½ Full)	50	0.024544	0.392699	0.062500
4	Steel	0.013	(½ Full)	50	0.043633	0.523599	0.083333
4	Fiberglass	0.009	(½ Full)	50	0.043633	0.523599	0.083333
6	Steel	0.013	(½ Full)	50	0.098175	0.785398	0.125000
6	Fiberglass	0.009	(½ Full)	50	0.098175	0.785398	0.125000
8	Steel	0.013	(½ Full)	50	0.174533	1.047198	0.166667
8	Fiberglass	0.009	(½ Full)	50	0.174533	1.047198	0.166667
10	Steel	0.013	(½ Full)	50	0.272708	1.308997	0.208333
10	Fiberglass	0.009	(½ Full)	50	0.272708	1.308997	0.208333
12	Steel	0.013	(½ Full)	50	0.392699	1.570796	0.250000
12	Fiberglass	0.009	(½ Full)	50	0.392699	1.570796	0.250000
14	Steel	0.013	(½ Full)	50	0.534507	1.832596	0.291667
14	Fiberglass	0.009	(½ Full)	50	0.534507	1.832596	0.291667

1. Use appropriate conversion factors for metric units.

1⁄16 in./ft. gradient slope = 0.00521		1⁄8 in./ft. gradient slope = 0.01042		1⁄4 in./ft. gradient slope = 0.02083		1⁄2 in./ft. gradient slope = 0.04167	
Discharge (gpm)	Velocity (fps)	Discharge (gpm)	Velocity (fps)	Discharge (gpm)	Velocity (fps)	Discharge (gpm)	Velocity (fps)
355.96	4.54	503.41	6.43	711.86	9.09	1006.84	12.85
528.86	6.61	747.94	9.35	1057.64	13.22	1495.91	18.70
14.30	1.30	20.22	1.84	28.59	2.60	40.44	3.67
20.65	1.87	29.21	2.65	41.30	3.75	58.42	5.30
30.79	1.57	43.55	2.22	61.59	3.14	87.11	4.45
44.48	2.27	62.91	3.21	88.96	4.54	125.8	6.43
90.8	2.06	128.4	2.91	181.6	4.12	256.8	5.83
131.2	2.98	185.5	4.21	262.3	5.95	371.0	8.42
195.6	2.50	276.6	3.53	391.1	4.99	553.2	7.06
282.5	3.61	399.5	5.10	565.0	7.21	799.1	10.20
354.6	2.90	501.5	4.10	709.2	5.79	1003.1	8.20
512.3	4.19	724.5	5.92	1024.4	8.37	1448.9	11.84
576.7	3.27	815.6	4.63	1153.3	6.54	1631.3	9.26
833.0	4.73	1178.1	6.68	1665.9	9.45	2356.3	13.37
870.0	3.63	1230.4	5.13	1739.8	7.25	2460.8	10.26
1256.6	5.24	1777.2	7.41	2513.08	10.48	3554.5	14.82

PRESSURE RATINGS

Fiberglass piping is available with a wide range of both internal and external pressure ratings depending on its intended application (see Tables D2.13 through D2.16). Pipe larger than NPS 16 (DN 400) is usually custom-made for the system pressure requirements. The piping system internal pressure rating is usually limited by the joining method and fittings, not the pipe. Long-term pressure ratings are extrapolated to a 50-year life expectancy using regression analysis (see Table D2.17).

TABLE D2.13 Fiberglass Process Piping (Internal & External Pressure Ratings for Pipe Manufactured According to ASTM D 2996 or ASTM D 2997)

NPS (DH)	Units	Internal pressure rating ranges*				External pressure rating ranges*	
		Vinyl ester		Epoxy		Vinyl ester	Epoxy
		Pipe	Fittings & joints	Pipe	Fittings & joints	Pipe	Pipe
1″ (25)	psi	735–950	50–950	450–950	150–950	1975–6400	360–2125
	MPa	5.07–6.55	0.34–6.55	3.1–6.55	1.03–6.55	13.6–44.1	2.48–14.7
2″ (50)	psi	200–850	50–850	450–1250	150–1250	330–2700	55–1170
	MPa	1.38–5.86	0.34–5.86	3.1–8.62	1.03–8.62	2.28–18.6	0.38–8.07
3″ (80)	psi	150–660	50–660	300–830	150–830	97–800	25–335
	MPa	1.03–4.55	0.34–4.55	2.07–5.72	1.03–5.72	0.67–5.52	0.17–2.31
4″ (100)	psi	125–510	50–510	175–785	150–785	45–340	16–225
	MPa	0.86–3.52	0.34–3.52	1.21–5.41	1.03–5.41	0.31–2.34	0.11–1.55
6″ (150)	psi	125–420	50–420	125–525	100–525	37–100	10–62
	MPa	0.86–2.9	0.34–2.9	0.86–3.62	0.69–3.62	0.26–0.69	0.07–0.43
8″ (200)	psi	100–360	50–360	125–450	75–450	21–56	10–45
	MPa	0.69–2.48	0.34–2.48	0.86–3.1	0.52–3.1	0.14–0.39	0.07–0.31
10″ (250)	psi	100–335	50–335	125–415	50–415	13–33	10–35
	MPa	0.69–2.31	0.34–2.31	0.86–2.86	0.34–2.86	0.09–0.23	0.07–0.24
12″ (300)	psi	100–280	45–280	125–350	50–350	10–23	7–23
	MPa	0.69–1.93	0.31–1.93	0.86–2.41	0.34–2.41	0.07–0.16	0.05–0.16

* ***Note:*** Ratings at ambient temperatures

TABLE D2.14 Fiberglass Line Pipe (Internal and External Pressure Ratings for Pipe Manufactured according to API 15LR or API 15 HR)

Nominal Size	Units	Internal pressure rating ranges	External pressure rating ranges
2″	psi MPa	300–4000 2.07–27.6	130–5700 0.9–39.3
3″	psi MPa	300–4000 2.07–27.6	60–5900 0.41–40.7
4″	psi MPa	300–4000 2.07–27.6	40–5600 0.28–38.6
6″	psi MPa	400–2500 2.76–17.2	225–2690 1.55–18.5

TABLE D2.15 Fiberglass Downhole Tubing (Internal and External Pressure Ratings)

Nominal Size	Units	Internal pressure rating ranges	External pressure rating ranges
1″	psi MPa	2000–3000 13.8–20.7	2000–4000 13.8–27.58
1½″	psi MPa	1000–4000 6.89–27.6	800–6000 5.52–41.37
2⅜″	psi MPa	1000–4000 6.89–27.6	800–6890 5.52–47.5
2⅞″	psi MPa	1000–4000 6.89–27.6	800–6680 5.52–46.06
3½″	psi MPa	1000–4000 6.89–27.6	700–6490 4.83–44.75
4½″	psi MPa	1000–4000 6.89–27.6	400–6700 2.76–46.19
7″	psi MPa	1000–3000 6.89–20.7	600–4500 4.14–31.03

TABLE D2.16 Fiberglass Casing (Internal and External Pressure Ratings)

Nominal size	Units	Internal pressure rating ranges	External pressure rating ranges
5½″	psi MPa	800–2000 5.52–13.8	80–3000 0.55–20.7
7⅝″	psi MPa	800–2000 5.52–13.8	80–3000 0.55–20.7
9⅝″	psi MPa	800–2000 5.52–13.8	70–3200 0.48–22.1

TABLE D2.17 Long-Term Hydrostatic Design Basis Ranges for Fiberglass Pipe per ASTM D 2992

Type	Units	Range
Vinyl ester process pipe	psi MPa	5000–9280 34.5–63.98
Epoxy process pipe	psi MPa	5000–31500 34.5–217.2
Line pipe	psi MPa	5560–15000 38.3–103.4
Casing	psi MPa	5000–15000 34.5–103.4

ABOVEGROUND DESIGN

Anchors Guides and Supports

It is important that an aboveground fiberglass piping system be properly anchored, guided, and supported. Anchors, guides, and supports must be selected which protect the piping components from point loads. Point loading can cause significant damage which will affect the life of the system. Figures D2.8 through D2.11 show typical hanger, support, guide, and anchor details.

Design Equations and Criteria

Design equations and criteria have been developed for fiberglass piping used in aboveground systems. These equations and criteria are conservative and have resulted in many numerous successful piping installations. Most of the fiberglass piping manufacturers publish technical information based on these equations and criteria.

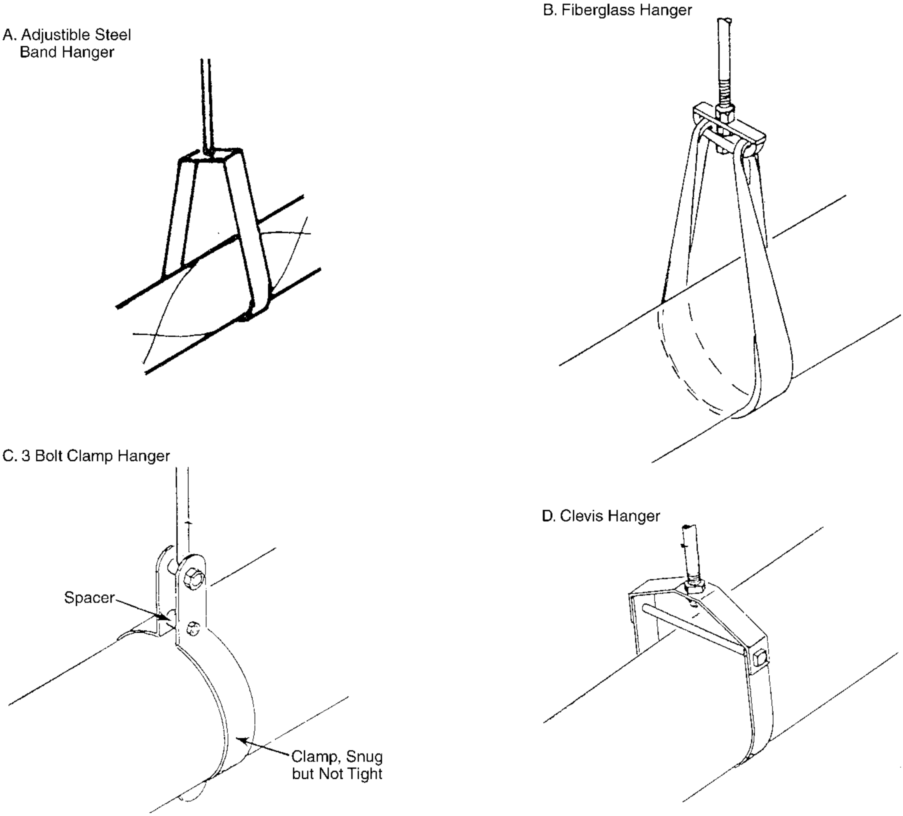


FIGURE D2.8 Typical hanger details. Pipe can move laterally and axially. (*Illustrations courtesy of Smith Fiberglass Products, Inc., Ameron Fiberglass Pipe Systems, and Fibercast Co.*)

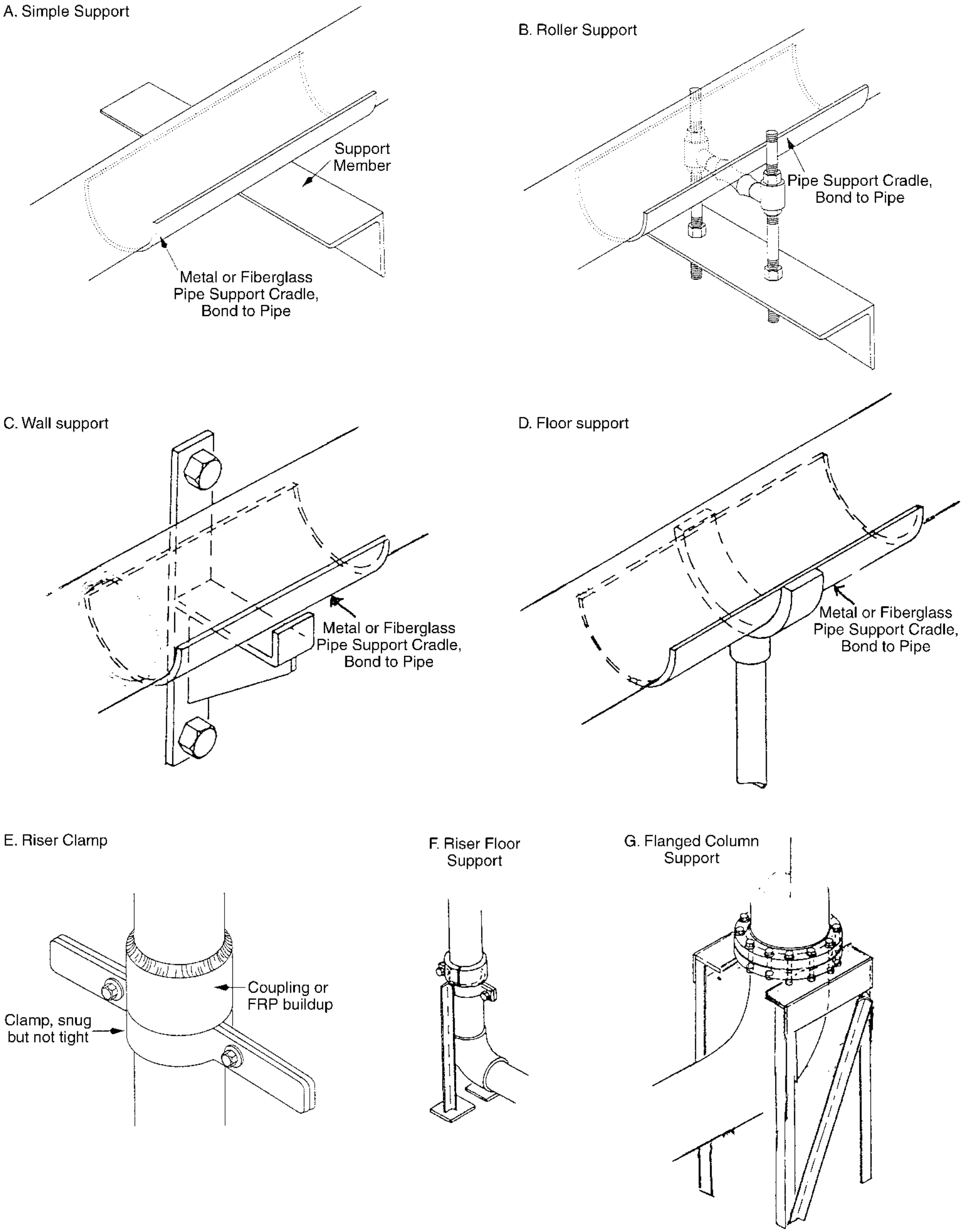


FIGURE D2.9 Typical support details. Pipe can move laterally and axially. (*Illustrations courtesy of Smith Fiberglass Products, Inc., Ameron Fiberglass Pipe Systems, and Fibercast Co.*)

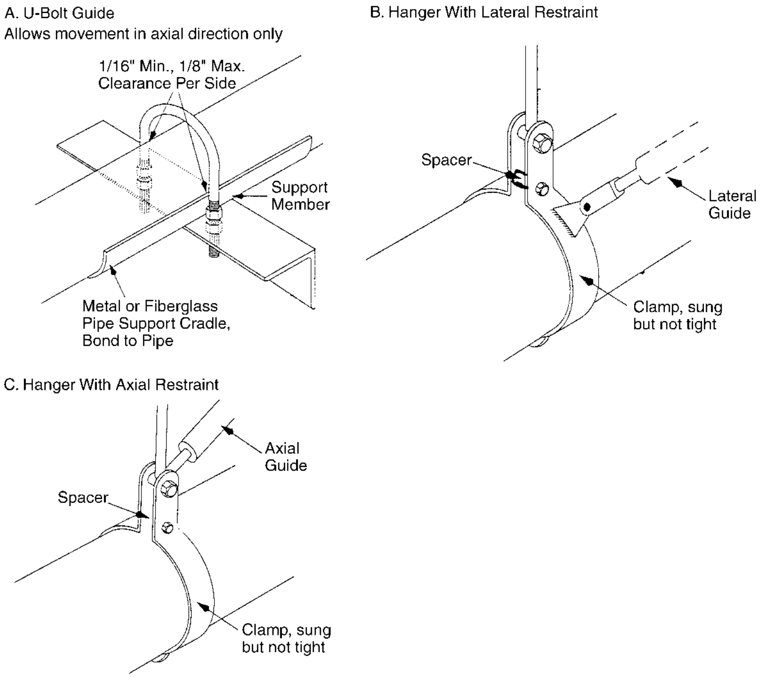


FIGURE D2.10 Typical guide details. Pipe is restrained axially or laterally. (*Courtesy of Fibercast Co.*)

Finite element computer design programs based on ASME design criteria are also used to design fiberglass piping systems. Use of one of these computer programs should be considered when designing complex systems. The manufacturer's published data should be used whenever doing design calculations or computer design.

Minimum Fiberglass Pipe Support Width. Fiberglass pipe can be damaged by point loads at hangers, supports, anchors, or guides. Hangers, supports, anchors, or guides should be selected which provide a minimum of 120° contact and a maximum bearing stress of 85 psi (6.0 kg/cm^2). Fiberglass pipe should be protected when used with support rollers, U-bolts, or flat supports such as angle iron or I-Beams (see Figs. D2.8 through D2.11). Eq. (D2.1) or Table D2.18 can be used to determine minimum fiberglass pipe support widths.

$$W = \frac{\sqrt{3}/2 * F}{\mathrm{OD} * Sb} \tag{D2.1}$$

where W = minimum support width, in (cm)
F = weight on support, lbs (kg)
OD = pipe outer diameter, in (cm)
Sb = allowable bearing stress 85 psi (5.98 kg/cm^2)
Based on 120° of contact.

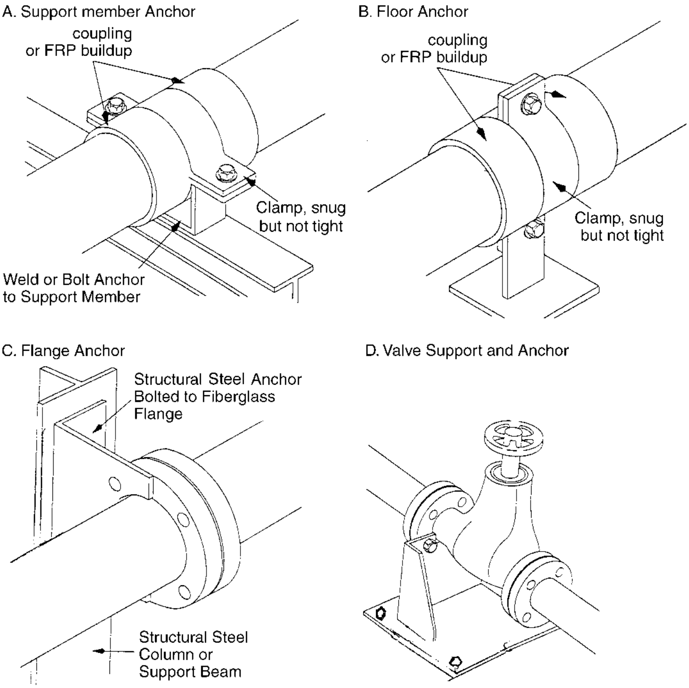


FIGURE D2.11 Typical anchor details. Pipe is restrained in all directions. (*Courtesy of Fibercast Co.*)

TABLE D2.18 Minimum Support Width for 120° Contact

Pipe size		Minimum support width	
NPS	DN	in.	mm
1	25	⅞	22.4
1½	40	⅞	22.4
2	50	⅞	22.4
3	80	1¼	31.8
4	100	1¼	31.8
6	150	1½	38.1
8	200	1¾	44.5
10	250	1¾	44.5
12	300	2	50.8
14	350	2	50.8

Note: Table is based on fluid specific gravity of 1.25 and typical maximum spans for filament wound fiberglass pipe at 75°F (24°C).

Example D2.1: 36 in nominal diameter pipe carrying 1.25 specific gravity fluid

F = weight of pipe plus weight of fluid times span length (32.5 lbs/ft + 550 lbs/ft) * 25 ft = 14,560 lbs

OD = 36.75"

$$W = \frac{\sqrt{3}/2 * 14560}{36.75 * 85} \Rightarrow 4.04''$$

TABLE D2.19 Deflection Coefficients, f, for Various Span Configurations

1 Span	2 Span	3 Span	4 Span
N—N f = 0.013	N—N—N f = 0.0069	N—N—N—N 1 2 1 f1 = 0.0069 f2 = 0.0026	N—N—N—N—N 1 2 2 1 f1 = 0.0065 f2 = 0.0031
F—N f = 0.0054	F—N—N 1 2 f1 = 0.0026 f2 = 0.0054	F—N—N—N 1 2 2 f1 = 0.0026 f2 = 0.0054	F—N—N—N—N 1 2 2 2 f1 = 0.0026 f2 = 0.0054
N—F f = 0.06	F—N—F f = 0.0026	F—N—N—F 1 2 1 f1 = 0.0026 f2 = 0.0031	F—N—N—N—F 1 2 2 1 f1 = 0.0026 f2 = 0.0031
	F—F—F f = 0.0026	F—F—F—F f = 0.0026	F—F—F—F—F f = 0.0026

Where: F = fixed securely, N = not fixed

Support Spacing for Fiberglass Pipe. Fiberglass pipe support spacing is determined using beam deflection equations. Deflection is normally limited to ½ in (1.27 cm). The resulting pipe bending stress is normally well below the allowable bending stress. Maximum pipe span based on deflection can be calculated using the following equation along with Table D2.20.

$$L = \left(\frac{d * Eb * I}{f * W}\right)^{0.25} \tag{D2.2}$$

where L = unsupported span length, in (cm)
d = allowable midpoint deflection, in (cm)
Eb = bending modulus of elasticity, psi (kg/cm^2)
l = pipe moment of inertia, in^4 (cm^4)
f = deflection coefficient. Table D2.19
W = weight of pipe and fluid, lbs/in (kg/cm)

Example D2.2: HPS 14 (DN 350) Pipe with Supports Securely Fixed,

$d = 0.5$ in
$Eb = 2 \times 10^6$ psi
$I = 226.12$ in^4
$f = 0.026$
$W = 7.08$ lbs/in

$$L = \left(\frac{0.5 * 2 \times 10^6 * 226}{0.0026 * 7.08}\right)^{0.25} \Rightarrow 333''$$

TABLE D2.20 Typical Fiberglass Pipe Maximum Support Spacing

Nominal pipe size, NPS (DN)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)
Support spacing, ft (m)	12½ (3.8)	14½ (4.4)	15 (4.6)	17½ (5.3)	19 (5.8)	21½ (6.6)	24½ (7.5)	26½ (8.1)	28 (8.5)	29 (8.8)

Note: Based on 4 span fixed continuous beam with a fluid specific gravity of 1. Use the following multipliers for other conditions.

Specific gravity	Span multiplier	Beam type	Span multiplier
1.25	0.95	Simple support, 1 Span	0.669
1.50	0.90	Continuous beam, 3 Span	0.783
2.00	0.84	Continuous beam, 4 Span	0.795

Thermal Expansion Calculation. Fiberglass pipe expands at from 1¼ times to twice the rate of steel pipe due to changes in temperature. The wide variation in thermal expansion is due to the different constructions used to make different types of fiberglass pipe. The following equation is used to calculate thermal expansion. Refer to Table D2.21.

TABLE D2.21 Typical Fiberglass Pipe Thermal Expansion, $C_t = 10.2 \times 10^{-6}$ in/in/°F (18.3×10^{-6} in/cm/cm/°C)

Temperature change, °F	25	50	75	100	125	150	175	200	225
Length change, in./100 ft.	0.31	0.61	0.92	1.22	1.53	1.84	2.14	2.45	2.75
Temperature change, °C	14	28	42	56	69	83	97	111	125
Length change, cm/30.5 m.	0.79	1.55	2.34	3.10	3.89	4.67	5.44	6.22	6.99

$$L_C = C_t * L * T_C \qquad \text{(D2.3)}$$

where L_c = length change, in (cm)
C_t = coefficient of thermal expansion, in/in/°F (cm/cm/°C)
L = Length of pipe between anchors, in (cm)
T_c = temperature change, °F (°C)

Example D2.3: NPS 14 (DN 350) Pipe

$Ct = 10.2 \times 10^{-6}$ in/in/°F
$L = 2400$ inches
$T_c = 100$ °F

$$L_c = 10.2 \times 10^{-6} * 2400 * 100 \Rightarrow 2.44 \text{ inches}$$

Restrained End Loads. Fiberglass pipes' low linear coefficient of thermal expansion, low compressive modulus of elasticity, and high compressive strength makes it practical to restrain the pipe to control thermal expansion. The following equation is used to determine the restrained end load for fiberglass pipe. Refer to Table D2.22 for typical heavy wall fiberglass pipe restrained end loads at rated compressive loads at 100°F (56°C) change in temperature.

$$E_L = C_t * E * A * T_c \tag{D2.4}$$

where E_L = thermal end load, lbs (kg)
C_t = coefficient of thermal expansion, in/in/°F (cm/cm/°C)
E = axial compressive modulus for expansion, psi (kg/cm^2) axial tensile modulus for contraction
A = reinforced cross-sectional area, in^2 (cm^2)
T_c = temperature change, °F (°C)

Example D2.4: NPS 14 (DN 350) Pipe

$Ct = 10.2 \times 10^{-6}$ in/in/°F
$E = 2.01 \times 10^6$ psi
$A = 9.4$ in^2
$T_c = 100$ °F

$$E_L = 10.2 \times 10^{-6} * 2.0 \times 10^6 * 9.4 * 100 \Rightarrow 19{,}200 \text{ lbs}$$

TABLE D2.22 Typical Heavy Wall Fiberglass Pipe Restrained End Loads and Rated Compressive Loads at 100°F (55.6°C) Temperature Change

Nominal pipe size, NPS (DN)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)
Restrained load, lbs × 10³ (kg × 10³)	0.83 (.37)	1.40 (.64)	1.60 (.73)	2.86 (1.3)	3.91 (1.8)	6.53 (3.0)	9.88 (4.5)	13.5 (6.1)	16.7 (7.6)	19.2 (8.7)
Rated compressive load, lbs × 10³ (kg × 10³)	2.99 (1.4)	5.23 (2.4)	5.36 (2.4)	9.94 (4.5)	14.4 (6.5)	22.1 (10)	34.8 (15)	44.8 (22)	57.7 (26)	69.8 (32)

Guide Spacing. When a fiberglass piping system is restrained to control thermal expansion, guides must be used to prevent pipe buckling. The following equation should be used to determine maximum guide spacing:

$$Lg = 0.262 * \left(\frac{Eb * I}{C_t * E * A * T_c} \right)^{0.5} \tag{D2.5}$$

where L_g = maximum distance between guides, ft (m)
E_b = bending modulus of elasticity, psi (kg/cm^2)

l = pipe moment of inertia, in^4 (cm^4)
C_t = coefficient of thermal expansion, in/in/°F (cm/cm/°C)
E = axial compressive modulus for expansion, psi (kg/cm^2)
A = cross-sectional area, in^2 (cm^2)
T_c = temperature change, °F (°C)

Example D2.5: 14" Pipe

$$Eb = 2 \times 10^6 \text{ psi}$$
$$L = 226.12 \text{ in}^4$$
$$Ct = 8.9 \times 10^{-6}$$
$$E = 2.1 \times 10^6$$
$$A = 12.912$$
$$T_c = 100\ °\text{F}$$

$$Lg = 0.262 * \left(\frac{2 \times 10^6 * 226}{8.9 \times 10^{-6} * 2.1 \times 10^6 * 12.912 * 100} \right)^{0.5} \Rightarrow 36 \text{ feet.}$$

Table D2.23 provides typical guide spacing for pipe sizes NPS l through 14 (DN 25 through 350).

TABLE D2.23 Typical Guide Spacing for Restrained Epoxy Pipe, Feet (meter)

Nominal pipe size, in (mm)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)
Temperature change										
50°F (28°C)	5.0 (1.5)	7.7 (2.3)	8.6 (2.6)	13 (3.9)	17 (5.3)	25 (7.7)	32 (9.9)	40 (12)	46 (14)	59 (18)
100°F (56°C)	3.5 (1.1)	5.4 (1.7)	6.1 (1.9)	9.2 (2.8)	12 (3.6)	18 (5.4)	23 (7.1)	29 (8.7)	34 (10)	42 (13)
150°F (84°C)	2.9 (0.9)	4.4 (1.3)	5.0 (1.5)	7.4 (2.3)	10 (3.0)	14 (4.4)	19 (5.8)	24 (7.2)	28 (8.5)	34 (10)
200°F (111°C)	2.4 (0.7)	3.8 (1.2)	4.3 (1.3)	6.5 (2.0)	8.5 (2.6)	12 (3.8)	17 (5.1)	21 (6.3)	24 (7.4)	30 (9.0)

Changes of Direction and Expansion Loops. Thermal expansion in fiberglass piping systems is often controlled using changes of directional or expansion loops. The low thermal expansion, low beam-bending modulus of elasticity, and high beam-bending strength of fiberglass pipe makes changes of direction and expansion loops very practical methods of thermal expansion control. The following cantilevered beam equations are used to determine the minimum leg lengths needed, based on allowable pipe stress or elbow bending moments. Minimum leg lengths based on pipe stress and elbow bending moments should be determined, and the longer of the leg lengths used.

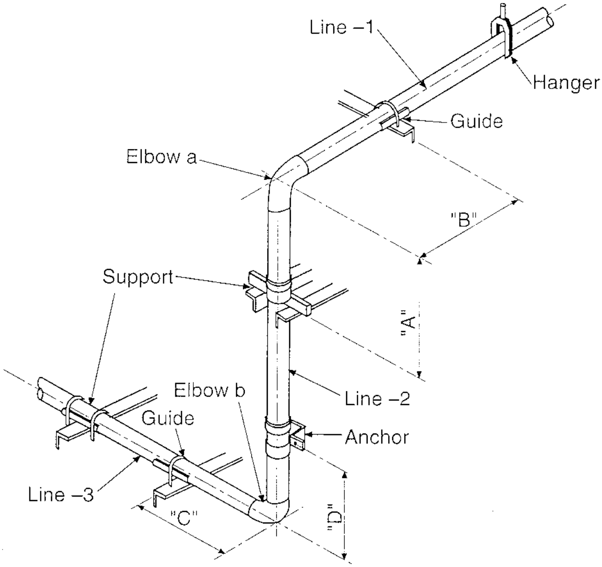


FIGURE D2.12 Offset leg sizing diagram.

Leg length based on pipe allowable bending stress (see Figs. D2.12 and D2.13):

$$A = \sqrt{\frac{K * L * E * \mathrm{OD}}{S}} \tag{D2.6}$$

where A = deflected pipe length, in (cm)
K = cantilevered beam constant
= 0.75 for expansion loops
= 1.50 for directional changes
L = length change, in (cm)
E = pipe-bending modulus of elasticity, psi (kg/cm^2)
OD = pipe outer diameter, in (cm)
S = pipe allowable bending stress (minimum 8:1 safety factor), psi (kg/cm^2)

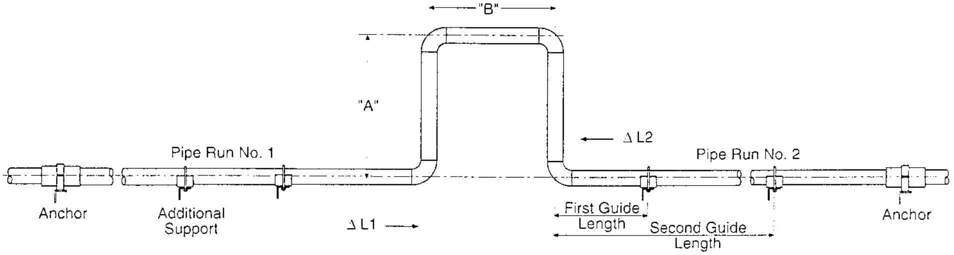


FIGURE D2.13 Loop leg sizing diagram.

TABLE D2.24 Typical Expansion, in (mm) versus Leg Length, ft (m)

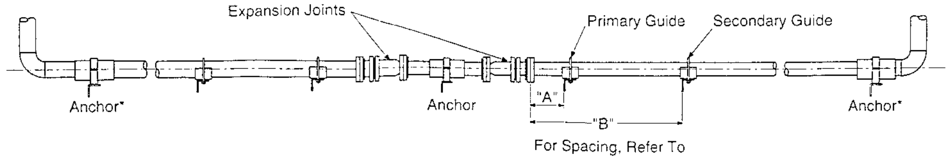
Nominal pipe size, NPS (DN)	1″ (25)	2″ (51)	3″ (76)	4″ (102)	5″ (127)	6″ (152)	7″ (178)	8″ (203)	9″ (229)	10″ (254)
1 (25)	4.6′ (1.4)	6.0′ (1.8)	7.1′ (2.2)	8.3′ (2.5)	9.1′ (2.8)	10′ (3.1)	11′ (3.3)	11′ (3.5)	12′ (3.8)	13′ (3.9)
1½ (40)	5.6′ (1.7)	7.7′ (2.3)	9.6′ (2.9)	11′ (3.3)	12′ (3.7)	13′ (4.0)	14′ (4.3)	15′ (4.6)	16′ (4.9)	17′ (5.1)
2 (50)	6.0′ (1.8)	8.3′ (2.5)	10′ (3.0)	12′ (3.5)	13′ (4.0)	14′ (4.4)	16′ (4.7)	17′ (5.0)	17′ (5.3)	18′ (5.6)
3 (80)	7.8′ (2.4)	11′ (3.4)	14′ (4.1)	15′ (4.7)	17′ (5.2)	19′ (5.8)	20′ (6.1)	22′ (6.6)	23′ (6.9)	24′ (7.3)
4 (100)	10′ (3.0)	14′ (4.2)	17′ (5.1)	20′ (5.9)	22′ (6.7)	24′ (7.3)	26′ (7.8)	27′ (8.3)	29′ (8.9)	31′ (9.4)
6 (150)	12′ (3.6)	17′ (5.2)	21′ (6.3)	24′ (7.2)	26′ (8.0)	29′ (8.8)	31′ (9.5)	33′ (10)	35′ (11)	37′ (11)
8 (200)	15′ (4.5)	20′ (6.2)	25′ (7.5)	28′ (8.7)	32′ (9.6)	35′ (11)	37′ (11)	40′ (12)	43′ (13)	45′ (14)
10 (250)	17′ (5.3)	24′ (7.3)	29′ (8.8)	33′ (10)	37′ (11)	41′ (12)	44′ (13)	47′ (14)	50′ (15)	53′ (16)
12 (300)	18′ (5.6)	27′ (8.2)	31′ (9.6)	36′ (11)	40′ (12)	44′ (13)	48′ (15)	51′ (16)	54′ (17)	57′ (17)
14 (350)	19′ (5.8)	27′ (8.1)	32′ (9.8)	37′ (11)	41′ (12)	45′ (14)	48′ (15)	52′ (16)	55′ (17)	58′ (18)

Leg length based on 90° elbow allowable bending moment:

$$A = \sqrt{\frac{12 * L * E * I}{M}} \qquad \text{(D2.7)}$$

where I = pipe reinforcement moment of inertia, in^4 (cm^4)
M = 90° elbow allowable bending moment, lb-in (kg-cm)

Table D2.24 provides typical expansion versus leg length.



*Anchor Load = $\frac{\pi}{4}$ (I.D.)^2 x (Internal Pressure)

FIGURE D2.14 Typical expansion joint installation.

TABLE D2.25 Distance from Expansion Joint to Primary and Secondary Guides (See Figure D2.14)

Nominal pipe size, NPS (DN)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)
Primary guide, "A", inches (mm)	5 (127)	8 (203)	10 (254)	12 (305)	16 (406)	24 (610)	32 (813)	40 (1016)	48 (1219)	56 (1422)
Secondary guide, "B", inches (mm)	18 (457)	30 (762)	36 (914)	42 (1067)	56 (1422)	84 (2134)	112 (2845)	140 (3556)	168 (4267)	196 (7518)

Expansion Joints. The thermal expansion loads and allowable loads for fiberglass pipe are relatively low when compared to metallic pipe. Therefore expansion joints selected for use with fiberglass pipe must have low activation forces. The following equation can be used to determine the maximum allowable expansion joint activation load:

$$Pcr = \frac{\pi^2 * Ec * I}{Lg^2} \tag{D2.8}$$

Where Pcr = critical buckling force of pipe, lbs (kg)
Ec = axial compressive modulus, psi (kg/cm^2)
l = pipe moment of inertia, in^4 (cm^4)
L_l = guide spacing interval, in (cm)

A primary and secondary guide should be used with expansion joints to give the joint proper alignment (see Fig. D2.14). Typically the primary guide is 4 nominal pipe diameters away from the joint and the secondary guide is 14 diameters away from the joint. Refer to Table D2.25.

BELOWGROUND DESIGN

Buried fiberglass pipe is treated as a flexible system where the pipe, trench walls, and bedding material work together to form a complete pipe support system. The elements of this system can best be defined by considering a section of buried flexible pipe and the loads acting on it. These loads, the *dead load* (*backfill*) and the *live loads* (*vehicle traffic*), act downward on the pipe, tending to deflect it into an oval shape. If the bedding material at the sides of the pipe is compacted sufficiently, it will resist the pipe movement and minimize the deflection to an acceptable amount. For this reason, the specification of the pipe, the construction of the trench, and selection of bedding materials must be closely coordinated and controlled.

Burial Design

The fiberglass pipe industry uses Chapter 5 American Water Works Association (AWWA) manual M45 as the design basis for buried pipe systems and Chapter 6 for installation guidelines. AWWA M45 Buried Pipe Design addresses internal pressure, surge pressure, external pressure, head losses, pipe properties, ring bending, deflection, soil loads, wheel loads, combined loading, modulus of soil reaction, buckling, and installation guidelines.

Trench Design

Fiberglass pipe is typically installed in trenches which provide from 2 ft to 20 ft (0.61 to 6.1 m) of cover when backfilled. Special designs have been developed for burial of pipe outside of this range. Trench design will vary depending on pipe diameter and specifications, type of soil, backfill, water table levels, and expected live wheel loads. (See Table D2.26 and Figs. D2.15 through D2.17). During installation it

TABLE D2.26 Nominal Trench Widths*

Nominal pipe size NPS (DN)	Minimum width earth excavation Inches (mm)	Maximum width Inches (mm)
2 (50)	18 (450)	26 (660)
3 (75)	18 (450)	27 (690)
4 (100)	18 (450)	28 (710)
6 (150)	20 (500)	30 (760)
8 (200)	23 (580)	32 (810)
10 (250)	25 (635)	34 (860)
12 (300)	28 (710)	36 (910)
14 (350)	31 (790)	38 (960)
16 (400)	33 (840)	40 (1010)
18 (450)	36 (910)	42 (1070)
20 (500)	39 (990)	44 (1120)
24 (600)	44 (1120)	48 (1220)
30 (750)	52 (1320)	56 (1420)
36 (900)	60 (1520)	64 (1630)
42 (1050)	66 (1680)	70 (1780)
48 (1200)	72 (1830)	80 (2030)
54 (1400)	78 (1980)	86 (2240)
60 (1500)	84 (2130)	96 (2440)
72 (1800)	96 (2440)	108 (2740)

* Trench widths may be wider depending on soil conditions.

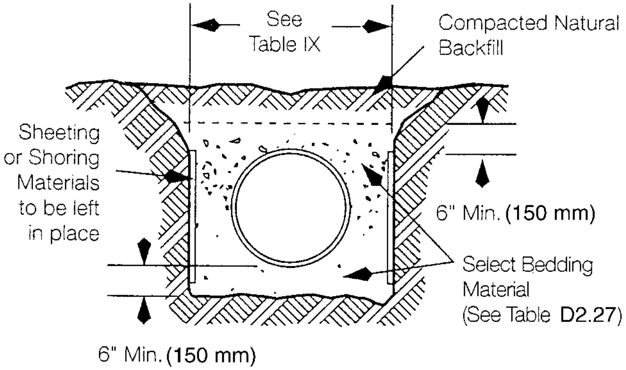


FIGURE D2.15 Trench shape and bedding for soft and medium consistency soil with sheeting or shoring.

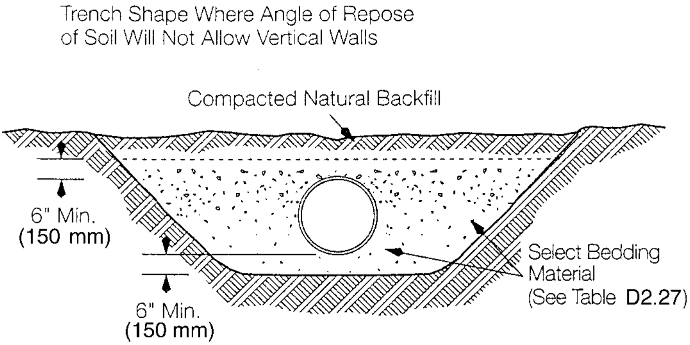


FIGURE D2.16 Trench shape and bedding for granular type soils (sand, etc.).

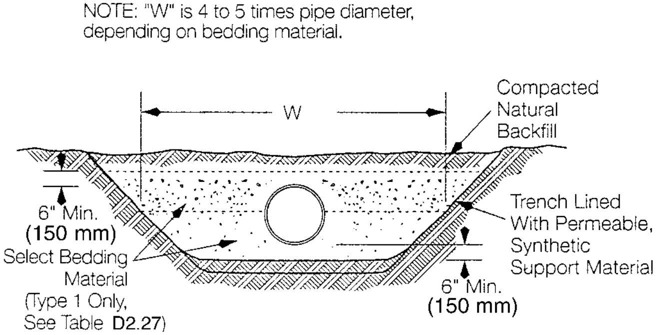
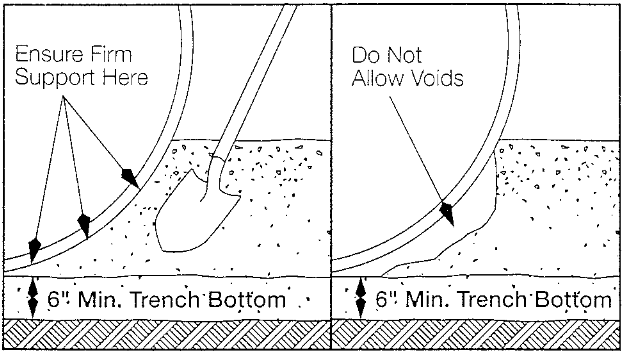


FIGURE D2.17 Wide trench for very soft consistency soils.



FIGURES D2.18 and D2.19. Flat trench bottom.

is very important that voids are eliminated around the bottom of the flexible fiberglass pipe. The bottom of the trench can be shaped to conform to the bottom ¼ pipe diameter, or, if flat, the bedding material carefully placed and tamped by hand to ensure complete pipe support (see Fig. D2.18 and D2.19).

Bedding Materials

Selection and compaction of bedding materials is critical to the success of a fiberglass buried pipe installation (see Table D2.27). Proper bedding will help prevent excessive deflection of the flexible fiberglass pipe. Bedding materials particle sizes should

TABLE D2.27 Bedding Material for Burial of FIBERCAST® Pipe

Type	Typical names	Description*	Unified soils classification system	Degree of compaction required†
1	Crushed rock or pea gravel	¾″ max. size with less than 50% passing No. 4 sieve	GW, GP	80–85%
2	Sand	Coarse or medium sand, moist	SW, SP	90–95%
3	Gravel, sand, clay and gravel, sand silt mixtures	Coarse grained soils 5% and 12% fines	GW-GM, GW-GC, SW-SM, GP-GM, SP-SM, GP-GC, SW-SC, SP-SC	85–90%
4	Silty gravels, clayey gravels, silty sands, clayey sands	Coarse grained soils more than 12% fines—low compressibility	GM, GC, SM, SC	90–95%

* All types have a maximum particle size of ¾ inch.
† Compaction required: Standard Proctor Density per ASTM D 698.

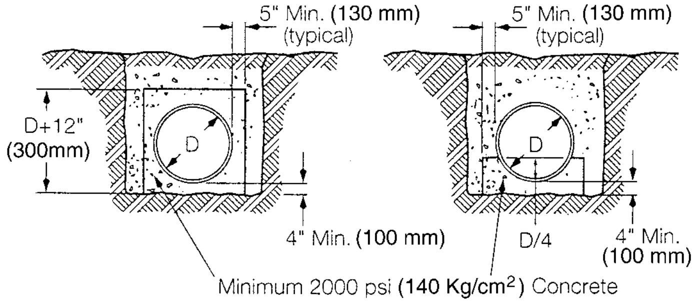


FIGURE D2.20 Typical Class "A" bedding.

be smaller than 3 times the pipe wall thickness to prevent point loading fracturing of the pipe walls.

High Water Table Areas

Areas with high water tables are usually coincident with very poor soil conditions. In most of these areas, it will be necessary to use crushed rock or pea gravel as the bedding and backfill material. In addition, a permeable, synthetic support fabric may be needed as a trench liner to prevent migration of the backfill material into the native soil.

In extreme cases such as soft clay and other plastic soils, it may be necessary to use "Class A" bedding (see Fig. D2.20). If the depth of the pipe cover is less than 1 pipe diameter, tiedowns or concrete encasement is recommended to prevent pipe flotation.

CONNECTION TO OTHER EQUIPMENT AND PIPING MATERIAL

Fiberglass pipe can be connected to other equipment and piping materials using flanges, threaded joints, and grooved adaptors. For flanges it is preferred to connect to flat-faced flanges. When connecting to flat-faced flanges, a full face gasket of 60 to 70 durometer Shore A hardness is usually used. Other specialty-type gaskets can be used, but the piping manufacturer should be contacted for compatibility. Fiberglass flanges can be damaged if excessive torque is applied to the flange or if the proper torque sequence is not followed. Again, the piping manufacturer should be contacted for information on maximum torque and torque sequence. In some cases a flat-faced flange cannot be used, such as on raised-face flanged pumps, valves, and other equipment. When connecting to a raised-face flange you can use a filament-wound fiberglass flange, a hard spacer ring, a steel backup ring, or machine the mating flange so that it is flat-faced. The hard spacer ring is used to fill the gap outside the raised face to prevent bolt loads from bending and breaking the fiberglass flange. In connecting with a flange to other equipment and piping materials, make sure the boltholes line up with the other system and have the same bolt hole pattern. Fiberglass flanges are available in a number of different hole patterns to match the connecting equipment. Fiberglass flanges should use a flat washer under all nuts and bolts used to make up the flange. Threaded joints are also used to connect to other equipment and piping materials. Threaded joints are typically available in NPT thread or 8 and 10 round EUE threads. Before making up threads in a fiberglass piping a system, make sure that all bonded joints are fully cured. Thread lube should be used which will not harden to seal the threads. Field threading of fiberglass piping is possible on some systems, and the manufacturer should be contacted for threading details. Grooved adapters are also available to make up to existing equipment and other piping materials. Fiberglass pipe connections to pumps and other equipment that involve vibration, shock loads, or other mechanical movement should include flexible connectors. Rotating equipment such as pumps can induce extreme vibration in the system if the natural frequency is reached. Flexible connectors used with fiberglass piping systems should have low activation forces due to the flexibility of the fiberglass pipe. When connecting to tanks the wall movement of the tank should be a consideration. Avoid direct connection between two tanks using fiberglass pipe. A change of direction should be utilized or a flexible connector to allow for tank wall movement.

INSULATION AND HEAT TRACING

It is common practice to use insulation and heat tracing for freeze protection in maintaining fluid temperature in fiberglass piping systems. The excellent insulating property of fiberglass piping may eliminate the need for additional insulation or heat tracing in some systems. The low conductivity of fiberglass piping should be considered when designing the system heat tracing and insulation. The additional weight and temperature of heat tracing and insulation should be considered when designing the unsupported spans for the piping system. The heat tracing used should not exceed the maximum temperature rating of the piping system. The maximum heat tracing temperature should also be used in all design calculations. It is very important that hot spots be avoided in the piping system, or damage to the fiberglass pipe can result. When using steam heat tracing, insulation can be placed between the heat tracing and the pipe to prevent hot spots. Thermally conductive tape designed for use with heat tracing can also be used to avoid hot spots in the piping. The most common form of heat tracing fiberglass pipe is with self-regulating electrical tape. Heat tracing should be spiraled around the pipe or run parallel down opposite sides of the pipe to prevent bowing of the system. Care should be taken when designing a system with heat tracing so that the flexibility inherent in a fiberglass piping system does not overstress the heat trace. Refer to Chap. B6.

PAINTING FIBERGLASS PIPING

Fiberglass piping systems can be painted to change the color of the piping or to coat a dulled surface. Fiberglass piping may become dull due to ultraviolet exposure from sunlight or from exposure to chemicals or chemical vapors. Fiberglass piping may have an exterior wax or silicone coating which will prevent adherence of the paint unless the piping is properly prepared. The piping can be prepared by sanding, sandblasting, or allowing it to weather until it has a dull surface. After the piping has been sanded or sandblasted, the surface must be cleaned in preparation for painting. Some paints may require primer before painting. Also, the paint must be compatible with the environment the pipe will be exposed to. Consult the paint manufacturer for details. Paints which have been found to work well with fiberglass piping systems are two component epoxies, two component urethanes, or alkyd enamels.

HYDROSTATIC TESTING

Fiberglass piping systems should always be tested prior to being put into service. It is very important that good hydrostatic test procedures be followed to prevent personal injury or property damage during the test. On aboveground systems all guides and supports must be in place prior to hydrostatic testing. On buried applications the piping should be partially backfilled, with the joints exposed prior to testing. Large or complex systems should be tested in subsections. One of the reasons for doing this is to confirm that proper fabrication techniques have been followed prior to fabricating the complete systems. If the piping system does not have any connections for testing, tie-ins may be required. These can be flange connections, threaded, or grooved connections. The connections can be cut off after the test. For drainage systems expandable plugs can be used for low-pressure testing, but because of the smooth bore of fiberglass piping, testing may be limited to less than five psi on larger diameters. The test pressure used should not exceed 1½ times the rated operating pressure of the lowest rated component of the piping system. If vacuum testing is used, the test should not exceed the external pressure rating of the piping system. The hydrostatic test can be either static or cyclic. For a static test the pressure is maintained in the system for 1 to 8 hours. For a cyclic test it is usually recommended that the pipe be cycled 10 times, from zero psi to 1½ times the rated operating pressure. Then the pipe has static pressure for a minimum of 1 hour. Water should be introduced into the system through a NPS 1 (DN 25) inlet for pipe up to NPS 14 (DN 350) and a NPS 2 (DN 50) inlet for pipe larger than NPS 14 (DN 350). While the water is being introduced, air must be bled from all the high points in the system to prevent the storage of energy which could result in damage to the system. Air can also be removed by using a small pig in the system. When filling and bleeding the system open and close valves slowly to prevent surges of water hammer, which can produce very high internal pipe pressures. When pressurizing the system, raise the pressure no more than 100 to 200 psi (690 to 1380 kPa) per minute. After the test pressure is reached, the system should be monitored for rises in pressure due to sunlight exposure, ambient temperature changes, or wind conditions. During the test when there is water in the system, freezing must be prevented in cold weather. Should leaks occur when the pipe is being tested, release the pressure immediately and repair the leak prior to retesting. When draining the system after the test, all the high points should be vented to prevent vacuum damage in systems not rated for a full vacuum operation.

Fiberglass downhole tubing requires some special precautions because the exterior of the pipe or tubing is normally pressurized with annular testing. If the tubing has a packer on the bottom of the strain, which is normal, the annular test pressure can increase the tensile load on the tubing if the packer moves. The combination of the annular test pressure and any fluid differential pressure must not exceed the external pressure rating of the tubing.

AIR TESTING

A hydrostatic test should be used instead of air or compressed gas pressure tests if possible. When air or compressed gas is used for testing, tremendous amounts of energy can be stored in the system. Many fiberglass pipe manufactures do not recommend air testing. If a failure occurs, the energy may be released catastrophically, which can result in property damage and personal injury. In cases where system contamination or fluid weight prevents the use of hydrostatic testing, air testing may be used with extreme caution. To reduce the risk of air testing, pressurize the system to no more than 15 psi (103.5 kPa). When pressurizing the system with air or compressed gas, the area surrounding the piping must be cleared of personnel to prevent injury. Hold air pressure for 1 hour, then reduce the pressure to one-half the original pressure. Personnel can then enter the area to perform a soap test of all joints. Again, extreme caution must be exercised during air testing to prevent property damage or personal injury.

SAMPLE SPECIFICATION FOR STANDARD WALL EPOXY FIBERGLASS PROCESS PIPING SYSTEMS

1.0 SCOPE

1.1 This specification covers requirements for machine-made NPS1 through NPS16 diameter fiberglass reinforced epoxy thermosetting resin processing piping for chemical petroleum, and industrial applications.

2.0 REFERENCED STANDARDS

2.1	ASTM D 1599	Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.
2.2	ASTM D 2105	Standard Test Method for Longitudinal Tensile Properties of ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.
2.3	ASTM D 2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
2.4	ASTM D 2992	Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.
2.5	ASTM D 2996	Standard Specification for Filament Wound ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.
2.6	ASTM D 2997	Standard Specification for Centrifugal Cast ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.
2.7	ASTM D 3567	Standard Practice for Determining Dimensions of ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.
2.8	ASME B31.3	Process Piping.

3.0 PIPE

3.1 The pipe shall be manufactured from epoxy resin to meet or exceed one of the following ASTM Standard Specifications for "Fiberglass" Pipe:

	Manufacturing Method	**ASTM Designation**	**Designation Code***
A.	Filament Wound	ASTM D 2996	RTRP 11FF1-3122
B.	Centrifugal Cast	ASTM D 2997	RTRP 21CW-4252

* Typical Designation Code May vary with product selected.

3.2 The pipe shall have a minimum 30 mil** thick epoxy resin liner as determined per ASTM D-3567. The liner shall have a minimum 65 percent by weight resin content.

** Liner thickness may vary by application.

3.3 The pipe shall have a minimum reinforced wall thickness per Table 1. Reinforced wall thickness shall be determined per ASTM D 3567. The reinforced wall shall have a minimum 45 percent by weight continuous glass roving content. Only epoxy resin shall be used in the reinforced wall.

TABLE 1

Nominal size NPS (DN)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)	16 (400)
Reinforced wall*** in (mm)	0.055 (1.4)	0.065 (1.7)	0.070 (1.8)	0.070 (1.8)	0.090 (1.8)	0.090 (2.3)	0.120 (3.0)	0.140 (3.6)	0.165 (4.2)	0.170 (4.3)	0.225 (5.7)

*** The reinforced wall may vary by application.

4.0 FITTINGS AND ADHESIVE

4.1 The pipe, fittings, and adhesive shall be produced by the same manufacturer. The piping, including joining method, shall have been commercially available from the manufacturer for a minimum of 5 years.

4.2 The piping system, including pipe, fittings, and joints, shall have a minimum pressure rating of 150 psig (1035 kPa) at 200°F (93°C). (Pressure and Temperature rating may vary by application.)

5.0 QUALITY ASSURANCE

5.1 Inspection for shipping damage shall be performed at the job site prior to piping installation. Damaged pipe and fittings shall not be used.

6.0 INSTALLATION

Installation, including joining, burial, anchoring, guiding, and supporting, shall be per the manufacturer's recommendations.

7.0 FABRICATOR CERTIFICATION

All fiberglass piping field joints shall be made by fabricators who have been certified by the piping manufacturer. Certification by the manufacturer shall be in compliance with ASME B31.3 section A328.2 for the type of joint being made.

SAMPLE SPECIFICATION FOR STANDARD WALL VINYL ESTER FIBERGLASS PROCESS PIPING SYSTEMS

1.0 SCOPE

1.1 This specification covers requirements for machine-made NPS 1 through NPS 16 diameter fiberglass reinforced vinyl ester thermosetting resin process piping for chemical petroleum, and industrial applications.

2.0 REFERENCED STANDARDS

2.1	ASTM D 1599	Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.
2.2	ASTM D 2105	Standard Test Method for Longitudinal Tensile Properties of ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.
2.3	ASTM D 2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
2.4	ASTM D 2992	Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.
2.5	ASTM D 2996	Standard Specification for Filament Wound ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.
2.6	ASTM D 2997	Standard Specification for Centrifugal Cast ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.
2.7	ASTM D 3567	Standard Practice for Determining Dimensions of ‘‘Fiberglass’’ (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.
2.8	ASME B31.3	Process Piping.

3.0 PIPE

3.1 The pipe shall be manufactured from vinyl ester resin to meet or exceed one of the following ASTM Standard Specifications for ‘‘Fiberglass’’ Pipe:

	Manufacturing Method	**ASTM Designation**	**Designation Code***
A.	Filament Wound	ASTM D 2996	RTRP 12EE1-2112
B.	Centrifugal Cast	ASTM D 2997	RTRP 22BU-4222

* Typical Designation Code May vary with product selected.

3.2 The pipe shall have a minimum 50 mil** thick vinyl ester resin liner as determined per ASTM D 3567. The liner shall have a minimum 65 percent by weight resin content.

** Liner thickness may vary by application.

3.3 The pipe shall have a minimum reinforced wall thickness per Table 1. Reinforced wall thickness shall be determined per ASTM D 3567. The reinforced wall shall have a minimum 45 percent by weight continuous glass roving content. Only vinyl ester resin shall be used in the reinforced wall.

TABLE 1

Nominal size NPS (DN)	1 (25)	1½ (40)	2 (50)	3 (80)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)	16 (400)
Reinforced wall*** in (mm)	0.075 (1.9)	0.080 (2.0)	0.085 (2.2)	0.090 (2.3)	0.090 (2.3)	0.110 (2.8)	0.130 (3.3)	0.150 (3.8)	0.160 (4.1)	0.160 (4.1)	0.200 (5.1)

*** The reinforced wall may vary by application.

4.0 FITTINGS AND ADHESIVE

4.1 The pipe, fittings, and adhesive shall be produced by the same manufacturer. The piping, including joining method, shall have been commercially available from the manufacturer for a minimum of 5 years.

4.2 The piping system, including pipe, fittings, and joints, shall have a minimum pressure rating of 150 psig (1035 kPa) at 175°F (79°C). (Pressure and Temperature rating may vary by application.)

5.0 QUALITY ASSURANCE

5.1 Inspection for shipping damage shall be performed at the job site prior to piping installation. Damaged pipe and fittings shall not be used.

6.0 INSTALLATION

Installation, including joining, burial, anchoring, guiding, and supporting, shall be per the manufacturer's recommendations.

7.0 FABRICATOR CERTIFICATION

All fiberglass piping field joints shall be made by fabricators who have been certified by the piping manufacturer. Certification by the manufacturer shall be in compliance with ASME B31.3 section A328.2 for the type of joint being made.

GLOSSARY

Catalyst. The chemical added to vinyl ester resins which cause them to harden. Usually Methyl Ethyl Ketone Peroxide (MEKP).

Centrifugal Casting. A process for making pipe in which resin and fiberglass are placed into the interior of a spinning rotary mold, forming the pipe through centrifugal force.

Chopped Fiber. Continuous glass fibers cut into short (0.125 to 2.0 in or 3 to 50 mm) lengths.

Chopped Strand Mat. Coarse fabric sheets made from chopped strands randomly placed and held together by resin binders.

Cure. The hardening of a thermoset resin system by the action of heat or chemical action.

Cure Time. The time it take for a resin system to reach full strength.

Curing Agent. Any of a number of chemicals added to epoxy resin to cause it to harden. Aromatic amine curing agents are commonly used for high-temperature corrosion service. Anhydride cured epoxy resins are typically used for less stringent applications.

Epoxy Resin. A thermosetting resin used in caustic, solvent, salt, and some acid solutions.

Fabmat. A combination of woven roving and chopped strand mat held together with resin binders. Usually used for making contact molded fittings and butt weld joints.

Filament. A single fiber of glass (e.g., a monofilament).

Gel Time. The time it takes for a resin system to harden so flow will not occur.

Hardener. Any of a number of chemicals added to resin which cause hardening to occur.

Liner. The resin-rich interior surface of the pipe or fitting. The liner provides the corrosion resistance for chemical service.

Nexus. Porous surfacing mat of synthetic used to provide a resin-rich layer or liner.

Novolac Resin. A premium epoxy vinyl ester resin used in a broad range of corrosive applications.

Reinforcement. Typically fibers of glass used to provide strength and stiffness to a composite material.

Resin. The polymer or plastic material used to bind the glass fibers together in fiberglass pipe and fittings.

Roving. A collection of one or more strands of glass filaments. The typical form of glass fiber used in the manufacture of filament-wound pipe.

Thermoset Resin. A resin cured by heat or chemical additives. Once cured, a thermoset resin cannot be remelted.

Veil. Surfacing mat of porous fabric made from filaments. Used to provide a resin-rich layer or liner.

Vinyl Ester Resin. A thermosetting resin used in strong acids, chlorine, and oxidizing agents.

Woven Roving. Coarse clothlike material made by weaving fiberglass roving.

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